APPENDIX FOUR a

ECONOMIC MODELLING FOR THE MAYOR'S MUNICIPAL WASTE MANAGEMENT STRATEGY

Economic Modelling for the Mayor's Municipal Waste Management Strategy

The Greater London Authority: PN497

Authors:

Adam Baddeley

Tim Elliott

Ann Ballinger

Chris Sherrington

Siobhan O'Brien

April 2010

Report for:

Doug Simpson, Greater London Authority

Prepared by:

Adam Baddeley (Project Manager)

Approved by:

Joe Papineschi

....

(Director)

Contact Details

Eunomia Research & Consulting Ltd
62 Queen Square
Bristol
BS1 4JZ
United Kingdom

Tel: +44 (0)117 9450100
Fax: +44 (0)8717 142942

www.eunomia.co.uk

(Project duration from September 2009 to April 2010)

Executive Summary

E.1.0 Introduction and Objectives

The first draft of the Mayor of London's Municipal Waste Management Strategy (MWMS) was published in early 2010. Further research and analysis with regard to economic modelling of waste management processes, is required before the document is published for consultation later in 2010. Eunomia Research & Consulting ('Eunomia') was tasked to provide an evidence base, on economic and environmental grounds, to provide context to the targets set out in the Draft Strategy, and whether any amendments are required.

The Project Specification for this study requested that a number of scenarios should be modelled to determine a 'Mayor's Preferred Method' for waste management. This method should be both technically feasible within the practical constraints of London's housing stock, and provide overall financial savings compared to a continuation of current practice.

The key elements of the Mayor's Draft MWMS, which have been used to guide the modelling undertaken for this study include:

- Waste reduction and reuse targets;
- Achievement of a minimum recycling/composting (or AD) rate of 45% by 2015, 50% by 2020 and 60% by 2031;
- Maintaining of the self sufficiency targets set out within the London Plan;
- Minimisation of waste sent to landfill, with only streams which have been through some kind of pre-treatment or sorting being sent to landfill;
- Increased collection and treatment of food waste;
- Support for residual waste treatments which maximise the abatement of greenhouse gases (GHGs);[1] and
- Financially viable opportunities for moving materials up the waste hierarchy.

The Draft MWMS was consulted upon by the London Assembly and Greater London Authority functional bodies until March 15th 2010. A revised draft document is due to be published for consultation in summer 2010, followed by publication of a final MWMS by early 2011.

E.2.0 Scope and Methodology

A total of 11 waste management scenarios involving different approaches to collection and residual treatment were modelled for this study. The sequence of the approach to developing both the scenarios and associated model can be summarised as follows:

- Development of a 'Do Nothing New' baseline;

[1] The goal of the Draft MWMS is not to be technology specific, but to request, as an output specification, that residual technologies are selected on the basis of their GHG performance

- Selection of a number of relevant 'Do Something' scenarios for comparison. These were, in essence, based around varying 'scheduled' household recycling collections and residual waste management processes; and
- For each scenario:
    - Modelling of changes in waste collection systems to meet overall targets;
    - Modelling of the costs of collection and treatment of all waste streams; and
    - Modelling of associated greenhouse gas (GHG) emissions;
    - Undertaking of 'risk analysis' and other forms of sensitivity analysis.

Key data sources for the study include WasteDataFlow (WDF) and other published research, such as another recent study undertaken on behalf of the GLA, on best performing collection systems in London, along with information developed on behalf of WRAP.[2] [3]

The main elements of waste management in London that were modelled in the study include:

- 'Scheduled' household dry recycling and organic waste collections;
- Reuse;
- Reuse and Recycling Centres (RRCs)
- Commercial Wastes;
- On-the-go Recycling;
- Organic waste treatment, i.e. composting and anaerobic digestion (AD); and
- Residual waste treatment.

Within our model, households in London were split into two key categories a) dwellings which receive a 'doorstep' type collection system and b) dwellings which receive a 'communal' type collection system. This is an important distinction with regard to development of assumptions relating to both the likely capture rates for recyclable materials and the cost of service delivery.

The five 'collection approaches' modelled in this study are described as:

- 'Do Nothing New' Baseline;
- 'Focus on Dry' recyclables;
- 'Focus on Food';
- 'Doorstep Only; and
- 'Max greenhouse gas (GHG) abatement'.

---

[2] Hyder Consulting (2010) The Performance of London's Municipal Recycling Collection Services, Final Report for GLA, March 2010

[3] Icaro Consulting (2009) Analysis of kerbside dry recycling performance in England 2007/08 (WRAP Project EVA034-087),Summary Report

These are combined with the following three waste treatment approaches:

- 'Do Nothing New' Baseline (i.e. existing landfill and incineration);
- 'New Tech (low-biomass / unrefined solid recovered fuel (SRF)' – includes mechanical biological treatment ('bio-drying') with a resulting low-biomass SRF sent for combustion or gasification; and
- 'New Tech (high-biomass / refined SRF)' – includes autoclaving with a high-biomass SRF sent for combustion or gasification, and plastics recovered for reprocessing.

Further information relating to the this determination of scenarios and the overarching modelling methodology is provided in Sections 3.0 and 4.0, with details of all assumptions presented in the Appendices.

E.3.0 Summary of Key Results and Recommendations

The key results from the study relate to the overall costs of waste management for London, and the CO_2 emissions associated with the resulting waste flows; these being the two most significant factors considered within the Mayor's Draft MWMS.

Based upon the results presented in Section 8.0 and the associated sensitivity analysis in Section 9.0, the following conclusions and recommendations can be made:

- Focusing waste management services on the maximisation of 'GHG benefit' could result in the lowest financial costs of any scenario modelled, as shown in Figure ES1. The Mayor, therefore, appears to be justified in proposing recycling targets above those within Defra's Waste Strategy for England, and might also be justified in raising these targets above those published under Policy 4 of the recent Draft MWMS;
- Figure ES1 shows that the 'Doorstep only' scenario, whereby no further increase in kerbside recycling from communal properties occurs, and all corresponding waste is diverted to MBT processes, appears to be more cost effective than both the 'focus on food' and the 'focus on dry' scenarios. It should be noted, however, that under this scenario, not enough materials can be recovered from the waste stream to meet the Mayor's 50% or 60% recycling target in 2020 and 2031 respectively. Therefore, the GLA should not seek to propose that a significant number of Boroughs follow such an approach;
- As stated throughout this report, a lack of available, verifiable data is such that there are significant uncertainties relating to estimates for some core collection cost and in some assumptions relating to service performance, especially out to 2031. As a result, the ranges of possible outcomes for each scenario (modelled using Monte Carlo analysis), as shown in Figure ES2 are relatively wide. Although the results of the study are of clear value, therefore, as with all macro-modelling of this nature, they should be treated with caution;

Figure ES1: Total (Annual) Costs of Waste Management in London in 2031

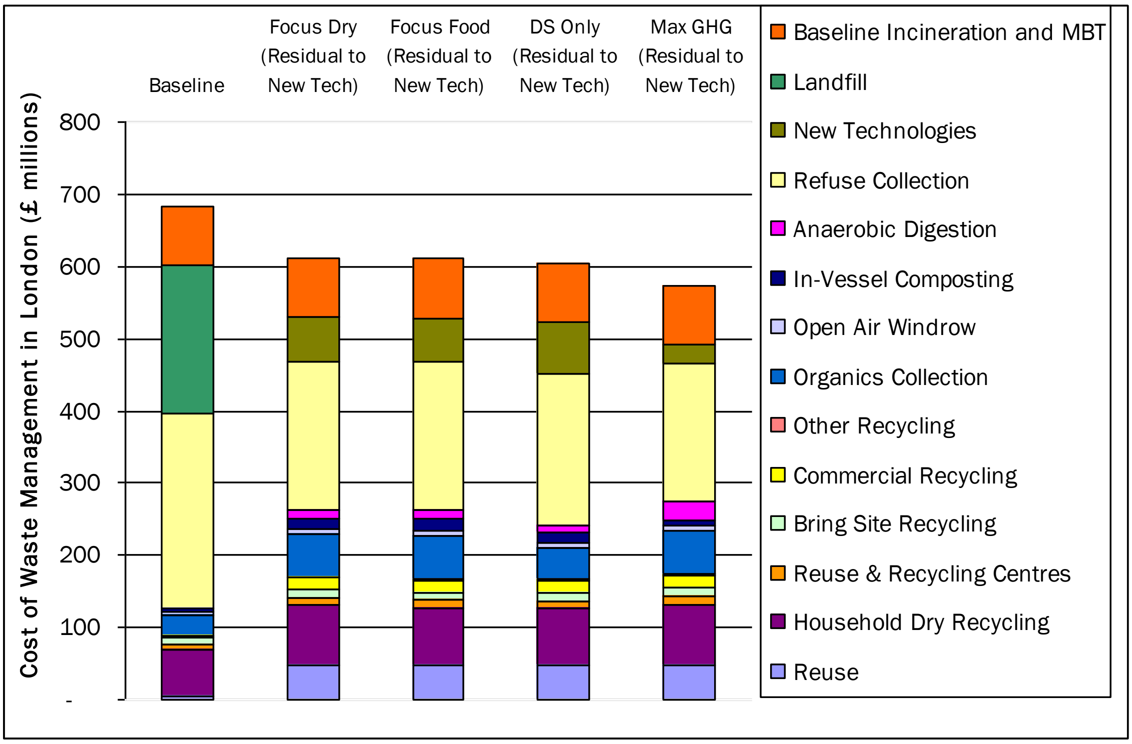
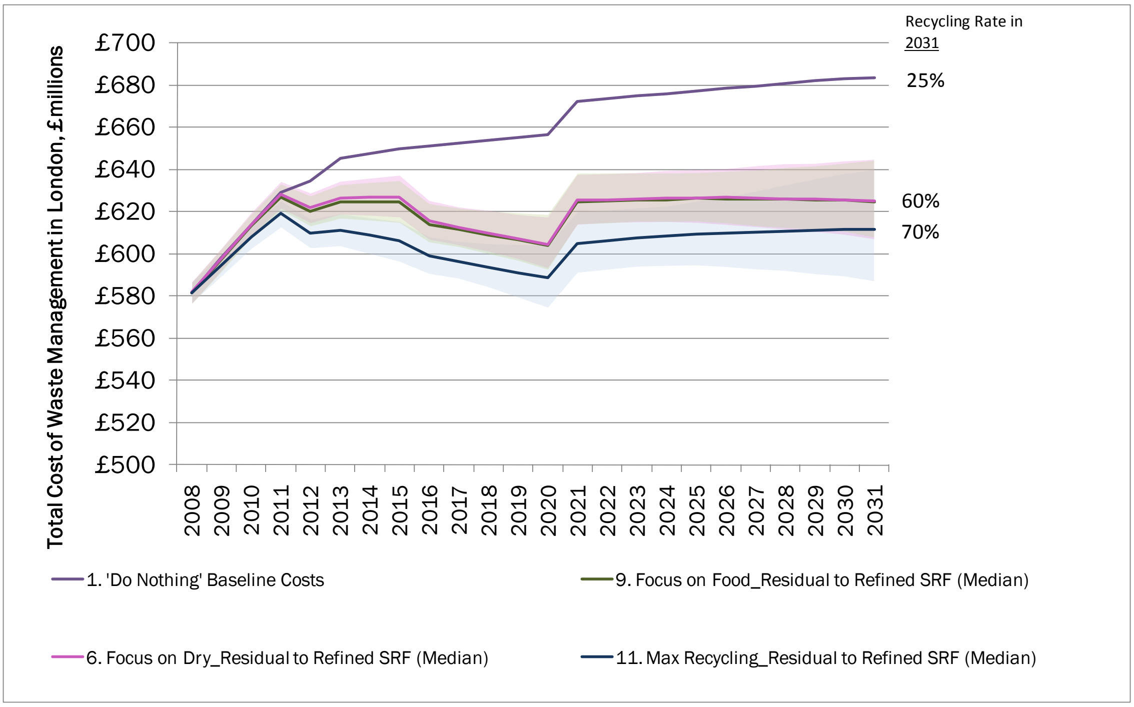


Figure ES2: Analysis of Total (Annual) Waste Management Costs to 2031



Note 1: Shaded areas represent the 95% confidence interval around the median values

Note 2: Scenarios 6, 9 and 11 have the same approach to residual waste management

- The approach towards maximising 'GHG benefit' is also consistent with the Mayor's proposal in the draft MWMS (Policy 2) for setting a greenhouse gas

(GHG) standard for MSW management activities to reduce their impact on climate change. Furthermore, Policy 5 of the draft MWMS proposes to catalyse low carbon technologies as a central element of new waste management infrastructure. The selection of new technologies modelled for each scenario, therefore, represent those which have been shown in a previous study by Eunomia on behalf of the GLA to offer better potential GHG performances than alternatives;[4]

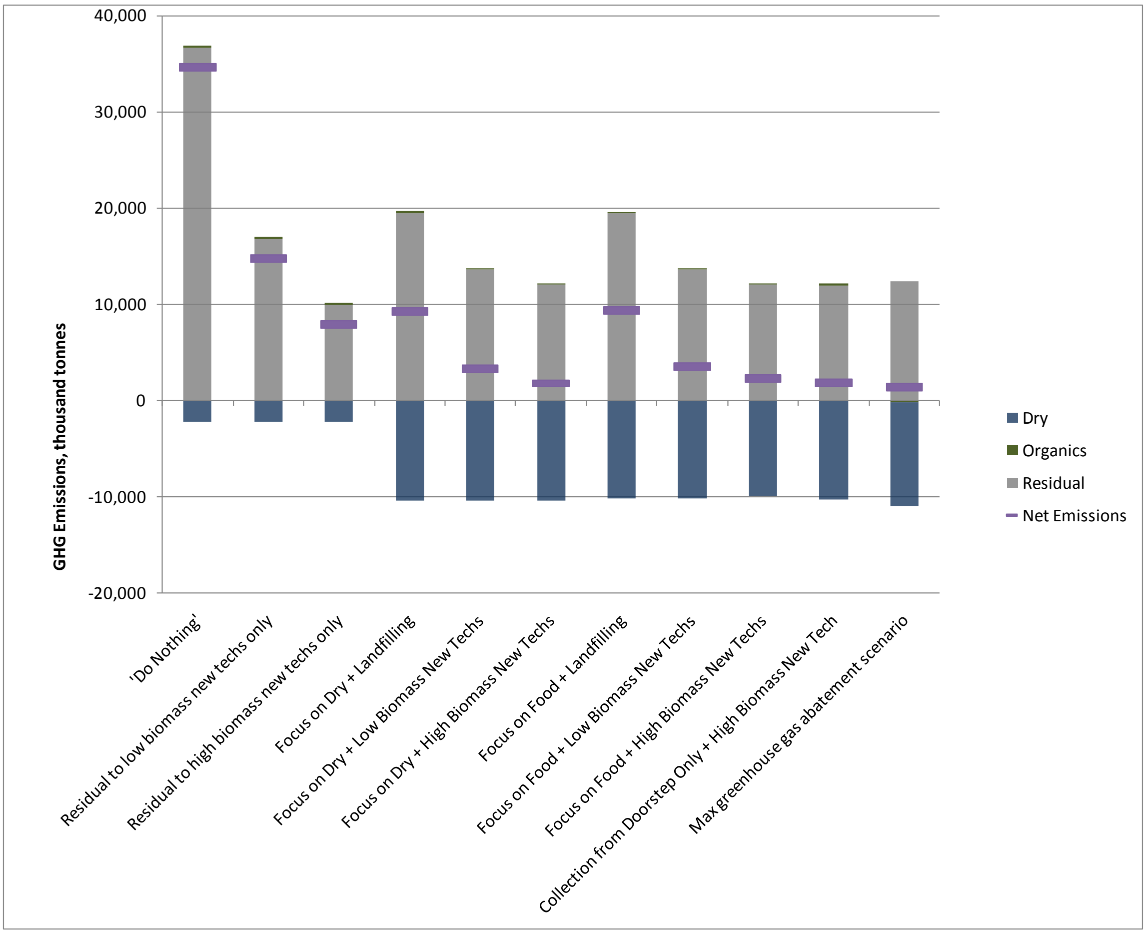
- The results of the study show that, with regard to reducing GHG emissions, all modelled scenarios perform significantly better than the 'Do Nothing' Baseline scenario (see Figure ES3). It should also be noted that there is relatively little difference in performance between the three core collection scenarios; 'focus on dry', 'focus on food' and 'max-GHG'.[5] In the recent consultation for a replacement draft London Plan, with regard to waste technologies, the GLA suggests shifting towards a more 'output-based specification to ensure the best possible environmental outcomes'.[6] It is therefore perhaps appropriate that this level of flexibility is given to the whole waste system, in that due to local infrastructure and housing stock it might be appropriate for some Boroughs to focus initial efforts on food waste collection, whilst others should focus initially on collection of additional dry materials to meet recycling targets. This might be a principle adopted by the GLA as part of the Mayor's emerging preferred method of waste management;

[4] Eunomia (2008) GHG Performance of Residual Waste Technologies, on behalf of the GLA, January 2008

[5] Furthermore, under the 'focus on dry 'and 'focus on food' scenarios, broadly the same amount of food and dry materials require collection to meet the 2015, 2020 and 2031 targets. The main difference between these two scenarios, therefore, is in the order of roll-out of services to 2015, which is shown in more detail in Appendix 4

[6] The London Plan: Spatial Development Strategy for Greater London (Consultation Draft Replacement Plan), 2009

Figure ES3: Breakdown of Cumulative GHG Emissions (2008 to 2031)



- The Mayor's Draft MSWM suggests that the total cost of waste management in London is in the region of £600m/annum. Albeit with the caveats relating to uncertainty outlined above, the modelling for this study (see Figure ES2 above) indicates a similar sum for future annualised costs under any of the given scenarios. Policy 3 of the Draft MWMS suggests that this annual cost might be reduced significantly, by as much as £90m/annum in near future. Whilst these savings might be optimistic in the short-term (in light of the rising costs of Landfill Tax and the time lag prior to the construction and operation of new management infrastructure), should the benefits of both markets for recycled materials and incentives for renewable energy be realised by London Boroughs via effective procurement of new services, they may be achievable in the medium to long term;
- The targets detailed under Policy 4 of the Draft MWMS present a specific challenge with regard to the timeframe to meet a 45% recycling rate by 2015, which reflects around a 20% increase on current performance. Assuming this target is met, subsequent targets will be far less challenging, with only a further 5% required over the following 5 years to 2020, then a further 10% to 2031. In initial years, therefore, annualised collection and recycling costs increase significantly for Boroughs. Over time, however, from 2015 to 2020, total annual costs decline slightly. This is the result of combination of effects including moderately increasing costs of collection of dry recyclables and

biowastes, falling costs of both refuse collection and landfill (albeit with increasing costs per tonne from the Landfill Tax escalator), such that the net impact is a year-on-year fall in total costs. From 2020, there is a need to replace ageing residual treatment infrastructure, i.e. the Edmonton incinerator, and thus total annual costs increase once more;

- It is understood that the Mayor proposes to promote an equal level of waste collection service across Boroughs. Whilst this might be a laudable goal, it should be noted that both this study, and a simultaneous report being undertaken on behalf of the GLA focusing on best practice collection, have found that this will be extremely challenging.[7] Some residential properties are simply not designed to cope with the amount of waste which is now generated by households, and whilst innovative systems such as underground vacuum technologies are being introduced in London, these come at a significant cost. Therefore, whilst we believe, as a principle, that the GLA might seek to promote minimum levels of collection service further to those enshrined in law via the Household Waste Recycling Act, it should also recognise that the barriers are such that this might not be appropriate for all Boroughs. At the same time, however, it should be recognised that other Boroughs might far exceed these minimum services, such that the overall objective is achieved on an aggregate basis;
- The evidence base used to model the costs of different waste management methods for this study suggests that collection and recycling or treatment of source separated wastes can be less expensive, on an annualised basis, than residual waste treatment processes. The order of dispatch in our model therefore is such that new collection services are generally rolled out prior to the development of new residual treatment infrastructure. If this is the case in reality, and new services achieve the levels of success delivered by best practice examples, it should be noted that London could find itself in the situation of having an over-capacity of waste management infrastructure. Whilst such a situation is perhaps currently perceived as being very unlikely, we recommend that the GLA is mindful of such an outcome in future years. By way of mitigating this risk, Eunomia has handed over the waste management model developed via this study, for use by the GLA on an ongoing basis, to monitor and analyse future waste flows in London;
- The modelling for this study suggests that the recycling targets proposed by the GLA in the Draft MWMS cannot be met by focusing on 'scheduled' household collection schemes alone. Improving performance at RRCs, and in commercial waste recycling (for which municipal-led services currently perform far worse than those operated by the private sector) will be essential. Furthermore, although the contribution of 'on-the-go' recycling and street cleansing activities is currently minor relative to other methods, the roll-out of new such services could play an important role, not least in improving the quality of life for many Londoners, in line with Policy 6 of the Draft MWMS;

[7] Hyder Consulting (2010) The Performance of London's Municipal Recycling Collection Services, Final Report for GLA, March 2010

- It should be acknowledged that meeting the proposed recycling targets does depend upon significant behavioural change, especially for residents in high-density housing and thus measures must be put in place to assist this change. Whilst detailed consideration of such methods is not within the scope of this study (and costs of communications campaigns, for example, have not been included within our model), the need to inform and educate Londoners towards changing behaviour is recognised and explored in some detail under Policy 1 in the Mayor's Draft MWMS;
- The modelling undertaken for this study does not include the costs of project development and consenting, which can be significant for waste management facilities, especially in urban areas. It should be noted, however, that the revised London Plan has been designed to smooth this consenting process, particularly if applications are based upon the use of cleaner waste treatment technologies;
- Although detailed consideration of whether LATS targets will be met is not a core element of this study and has not been quantitatively demonstrated within, our high-level analysis indicates that, for London as a whole, these will be met under each of the core scenarios, as is shown within the Mayor's Draft MWMS; and
- Whilst there has been significant focus within this study (and in much previous work relating to waste management in London) on GHG emissions, it is important to highlight the potential tension between the development of low-carbon waste treatment plant and the minimisation of air quality impacts. Primarily these relate to oxides of nitrogen (NOx) and particulates (PM10), for which London is currently estimated to be exceeding targets.[8] Recent work undertaken by Eunomia and EMRC on behalf of the GLA showed that the development of new plant might result in exceedances of both NOx and PM10 in specific locations, particularly those near to busy roads. The study concluded, however, that there are large areas of London where waste treatment plant could be located with minimal effect on attainment of air quality objectives. Isolated residual treatment facilities of the types considered in this study - if managed and operating as designed - were therefore considered to be unlikely to have a significant effect on air quality where objectives are not forecast to be exceeded in the future.

[8] GLA (2002) Cleaning London's Air: The Mayor's Air Quality Strategy, September 2002

Contents

1.0 Background and Introduction

The first draft of the Mayor of London's Municipal Waste Management Strategy (MWMS) was published in early 2010. Further research and analysis with regard to economic modelling of waste management processes, is required before the document goes out for consultation later in 2010. Eunomia Research & Consulting has been tasked to provide an evidence base, on economic and environmental grounds, to provide context to the targets set out in the Draft Strategy, and whether any amendments are required.

The Project Specification issued by the Greater London Authority (GLA) requested that a number of scenarios should be modelled to determine a 'Mayor's Preferred Method' for waste management. This method should be both technically feasible within the practical constraints of London's housing stock, and provide overall financial savings compared to a continuation of current practice.

The key elements of the Draft MWMS upon which the modelling within this study are focused include:

- Reduction and reuse targets;
- Achievement of a minimum recycling/composting (or AD) rate of 45% by 2015, 50% by 2020 and 60% by 2031;
- Maintaining of self sufficiency targets set out within the London Plan;
- Minimisation of waste sent to landfill, with only streams which have been through some kind of treatment or sorting being sent to landfill;
- Increased collection and treatment of food waste; and
- Support for residual waste treatments which maximise the abatement of greenhouse gases (GHGs).[9]

As mentioned above, the Draft MWMS is currently being consulted on by the London Assembly and Greater London Authority functional bodies until March 15 2010. A revised Draft document is due to be published for consultation in summer 2010, followed by publication of a final MWMS by early 2011.

[9] The goal of the Draft MWMS is not to be technology specific, but to request, as an output specification, that residual technologies are selected on the basis of their GHG performance

2.0 Project Scope and Objectives

The Mayor's intention is that this study will function as an independent piece of supporting evidence to his new MWMS. In the Project Specification received by Eunomia, two core objectives were stated, as follows:

- To model a range of waste management scenarios using London-specific waste data and present the results with regard to economic performance; and
- To develop a waste management tool for the GLA to use on an ongoing basis to model the costs associated with waste management scenarios in London.

Along with the results of the modelling exercise, this report is therefore focused on providing details of the key assumptions which underpin both these results, and the spreadsheet model handed over to the GLA for future use. This model includes information at the Borough level to reflect both the current 'real-life' waste flows and the impacts of future plans for new or amended services within London.

The study includes a range of waste management scenarios, which are modelled against a baseline 'Do Nothing New' scenario. Eunomia's approach to selecting and modelling these scenarios is further detailed in Section 4.0.

To bring in an element of cost-benefit analysis (CBA) to the study, Eunomia has provided information relating to the GHG emissions associated with each of these waste management scenarios. As per previous work by Eunomia on behalf of the GLA, these emissions have been monetised, such that these can be more easily compared and reconciled with economic costs.

The timescales associated with the modelling extend from latest waste arisings data (2008/09) until the final year considered in the Mayor's Draft MWMS (2031/32).

3.0 Methodology

The sequence of the approach to developing both the scenarios and model can be summarised as follows:

- Develop a 'Do Nothing New' baseline;
- Select a number of relevant 'do something' scenarios for comparison;
- For each scenario:
    - Model changes in collection systems to meet overall targets;
    - Calculate the costs of collection and treatment of all waste streams; and
    - Calculate relevant environmental impacts.
- Run sensitivities.

In this Section, the development of the 'Do Nothing New' baseline is described in Section 3.1, followed by additional elements required for the modelling (i.e. waste growth and composition development) in Sections 3.2 and 3.3, the principles involved in modelling all other 'Do Something' scenarios in Section 3.4, and finally a brief discussion around the monetisation of GHG emissions is provided in Section3.5.

3.1 'Do Nothing New' Baseline Development

There are two elements to the baseline used in the model. Firstly a mass flow baseline was constructed to show the management of different wastes by treatment or disposal method. The second element is the 'collection system' baseline. The distinction is made because, when modelling the costs of waste management in each scenario, these cannot always be directly related to the tonnage of waste collected. For example, in terms of household waste, the multiple collection systems that can exist at one property make analysis of the cost of collection, in terms of one tonne of waste collected, very complex. It is therefore more sensible to calculate collection costs per household, as has been undertaken for this study.

3.1.1 Data Sources and Gathering

Defra and The Environment Agency's WasteDataFlow (WDF) tool is an obvious starting point in determining current waste flows. Our experience indicates, however, that even following significant interrogation of this tool, there usually remain unanswered questions with regard to how Boroughs are currently managing specific materials, for example, whether recyclables are collected in separated or co-mingled form, or how materials are collected in terms of frequency and container type. The information for this study has therefore been drawn from a simultaneous study undertaken on behalf of the GLA, which involved interviews with each London Borough to determine and corroborate the following:[10]

- Future plans for new or amended services;
- Recycling collection scheme characterisation, i.e. frequency, containers;
- Performance (in kg/household) of each recycling collection scheme;
- Refuse collection scheme characterisation, i.e. frequency, containers; and
- Costs of service delivery.

Where this data is unavailable, for example incomplete data returns in WDF, we have used previously gathered data or contacted the Boroughs directly.

3.1.2 Analysis of Current Situation

The analysis of the data described in Section 3.1.1 focuses on the following two key parameters:

1. The nature of the collection systems in place in each Borough (for dry recyclates, organics and refuse); and
2. The tonnage collected for each material. This is to give an indication of the overall performance of the systems (at Borough level, and system level where possible).

From this analysis, the current (2008/09) situation was developed as a basis for the 'Do Nothing New' baseline. Sections 3.1.2.1 to 3.1.2.3 add further detail to the development of this baseline, through discussion of the main waste streams arising in London.

3.1.2.1 Household Kerbside Waste

It should be noted that two housing types have been examined in the modelling. Households receiving a *doorstep* collection have been separated from households on a *communal* collection. This difference in type of collection system was deemed one of the most important factors in developing the modelling of kerbside services in London. Performance and cost are assumed to differ to a greater extent than the classification of housing types, as reported by organisations such as the ONS. In this report, we therefore refer to the costs and performance on this basis.

The data on kerbside schemes is more comprehensive than for any other type of waste collection system. However, such schemes are constantly changing and the reporting of data varies between Boroughs. Moreover, reporting varies depending on the nature of the questions posed to LAs. This makes cross comparison between WDF information and that gathered in surveying of Boroughs very important.

---

[10] Hyder Consulting (2010) The Performance of London's Municipal Recycling Collection Services, Final Report for GLA, March 2010

In our model, tonnage data was extracted from WDF for each Borough and aggregated to calculate the levels of recycling and residual waste management. The destination of the treatment / disposal options was also used to calculate baseline disposal costs.

For each Borough, information was compiled to show the types of recycling and organic schemes in place for each housing type. Information on the type of refuse collection in place was also compiled, as the frequency and type of container has significant implications for the overall cost of the service. For the purposes of this study, we have called this the 'collection system' baseline.

3.1.2.2 Non-household Municipal Wastes

Non-household municipal waste is estimated to account for 21% of all the municipal waste in London, most of which is commercial waste from local small-medium sized businesses. This is a relatively high proportion compared to the national average. It is therefore important to seek to understand what is happening with commercial waste collection and onward management. However, despite this goal, there remains very limited data on the collection systems employed nationally, let alone at a Borough level. Furthermore, although there is some tonnage data from recycling collections available from WDF, the types of system are not known, and will vary considerably depending on the type, and size of businesses.

3.1.2.3 Other Municipal Wastes

The other sources of large quantities of waste from the municipal sector include Reuse and Recycling Centres (RRCs) and, to some extent, bring bank sites. Whilst 'on-the-go' recycling and other collections have a lesser impact, we have also included these routes within the model, although it should be noted that data on these later sources of waste is very immature and thus not considered wholly reliable.

For each Borough the number of RRCs and bring sites (by material) were included in the model baseline. Furthermore, for all waste sources noted above, the total tonnage of materials collected for recycling / disposal was also considered. Again, this information was taken from WDF.

3.2 Waste Arisings and Change over Time

Current waste arisings were taken from the latest WasteDataFlow reports (2008/09). Changes in waste arisings are based on a recent study undertaken on behalf of the GLA.[11] The study seeks to understand what impacts various factors, such as waste prevention and population growth, will have on the total waste generated in London.

The key conclusions and assumptions used in the modeling for this study can be summarized as follows:

---

[11] LRS / SLR (2010) Future Waste Arisings in London, 2009 - 2031: Project summary and methodological memo., 2010

- The number of households in London will continue to increase. A 17% increase by 2031 is forecast;
- Household waste arisings, per household, will decrease over time, as a result of waste prevention effects considered to arise through communication campaigns, and additional service provisions;
- The combination of <u>increased</u> housing and <u>decreased</u> waste, per household, means that the absolute growth in household waste will be zero; and
- In the absence of any waste prevention activities, non-household municipal waste will grow by 30% by 2031.

These growth rates are included in our 'Do Nothing New' baseline, as well as the 'Do Something' scenarios.

3.3 Waste Compositions

Assumptions relating to waste composition play a part in determining the costs of different management methods. For example, the calorific value (CV) of streams being sent for energy recovery will affect the level of energy output, and thus revenues from the facility with regard to energy sales and revenues from Renewable Obligation Certificates (ROCs). The model therefore has the capability to calculate varying energy outputs which relate directly to the composition of the residual waste.

Furthermore, compositions are needed to estimate the likely yields of recyclable materials, based on a systems performance. This is true for not only household-kerbside waste, but also waste arising at RRCs, street litter bins, and commercial properties.

Full details of the data sources and compositions used in this work are given in Appendix 2. The following points summarise the approach:

- Kerbside-collected Household Wastes – composition taken from the latest *Resource Futures* analysis of England's Municipal waste;
- RRCs / Litter – taken from 2006 AEA study for the Welsh Assembly Government (WAG);
- Commercial Wastes – derived from latest WAG C&I survey (07/08) and from previous AEA study; and
- Residual Composition – derived using the latest municipal compositional survey, and estimations regarding the likely capture of materials required to meet overall recycling rates (we determine four generic compositions, low, mid - with and without food collections – and high, within this study).

3.4 Approach to 'Do Something' Scenario Modelling

Following the modeling of the 'Do Nothing New' baseline we modeled 11 scenarios whereby there is some change to this baseline. The varying scenarios reflect a range of realistic situations for waste management in London. The process of determination of these scenarios is discussed in detail Section 4.0.

Sections 3.4.1 to 3.4.6 summarise the overarching approach to modelling these 11 ‘Do Nothing New’ scenarios, with assumptions for specific scenarios provided in Section 4.0.

3.4.1 Modelling of Waste Collection

In ONS census data from 2000, 36 to 49% of London’s housing stock was described as flats.[12] The aforementioned Hyder study indicates that ‘doorstep flats’, ‘near entry flats’ and ‘flats above shops’ account for some 45% of the current housing stock in London. There will be some cross-over between houses and ‘flats’ as , under the classifications in the data sources mentioned above, ‘flats’ also relates to houses within which separate rooms are rented out as ‘flats’. Consequently, some ‘flats’ will receive a ‘doorstep’ type collection service, but most will be serviced by a ‘communal’ based system.

In the modelling we use existing data sources on waste collection services in London to categorise properties as ‘doorstep’ and ‘communal’ rather than by building type. Our understanding of *recycling* collection systems in London suggests that around 32% of households in London receive a ‘communal’ type service. Potential limitations to the use of ‘scheduled’ household collection systems for such properties are taken into consideration within our modeling of scenarios.[13]

Data relating to the yield of different materials from a range of collection systems, on a per household basis, is combined with total household figures to estimate overall captures of waste. It should be noted that these yield figures were inflated for London as current household arisings, per capita, are higher than the average for the UK.

To enable modelling of like-for-like collection costs of new services, the cost baseline and cost of additional services is drawn from data within Eunomia’s internal cost model. This includes elements to calculate the collection costs of dry recyclables, organics and refuse. The dry recycling ‘collection only’ costs for ‘doorstep’ properties are drawn from a study undertaken on behalf of WRAP.[14] Data relating to costs of collecting recyclables from ‘communal’ properties is very limited. One study previously undertaken by Eunomia, which considered the costs of collection from flats in Hackney is used as the main data source for this study.[15]

The approach undertaken demonstrates the change in costs associated with different scenarios, along with providing absolute values. The aforementioned Hyder study on

---

[12] This wide range relates to the inclusion / exclusion of ‘shared dwellings’ in the ONS data. This category could relate to flats or houses, depending on the how they are classified

[13] We have used the term ‘scheduled’ in this study to refer to services which happen on a regular, scheduled basis, for example, kerbside collections from households. All other collection services are deemed ‘non-scheduled’ for the purposes of this study

[14] WRAP (2008) *Kerbside Recycling: Indicative Costs and Performance. Technical Annex,* Available at: http://www.wrap.org.uk/downloads/KerbsideReportAnnexFinal_1.bac022de.5634.pdf

[15] Eunomia (2007) Estates Recycling Evaluation; Report for the London Borough of Hackney, January 2008

recycling performance in London attempted to gather information from Boroughs on the *collection cost* element of recycling services. Limited data was received from the Boroughs, and where cost information was supplied, annualised costs of service were given, not the collection only cost of the different systems. Therefore, limited 'London specific' data has been available for the modelling in this study.

The sequence of changes modelled for scheduled household collections is summarised in Sections 3.4.1.1 and 3.4.1.2.

3.4.1.1 Scheduled Household Organics Collections

1. For each Borough the preferred marginal collection system for households which are not currently receiving a garden or a food waste collection is considered:
   a. In most cases this is the existing system currently in place, i.e. we do not change any existing garden waste services in the model, and only roll out services to households not covered by the existing scheme; and
   b. For 'doorstep' properties, existing food waste collection services are rolled out to further households in the Borough. Where no collection system is in place, source separated food waste collection services are rolled out. For 'communal' properties, only source separated collections are rolled out; the assumption being that all garden waste from these properties is currently managed, and that no additional collections are required.
2. The roll-out of new collection systems follows a 'cost effective' approach. For example, all households not receiving a service are categorised by the preferred system described above. The households for which this preferred system is cheapest (based on modelling of all systems as part of this study) are those which receive a new collection system first. Then, in a sequential order, households with the next cheapest preferred system receive a new service, and so on.

3.4.1.2 Scheduled Household Dry Recyclable Collections:

1. For 'doorstep' type properties 'best practice' dry recycling services (for both source separated and comingled) are considered. The change in costs between the existing system and the 'best practice' system are calculated. Households for which this change in costs is the smallest are those for which this change is made first. In general, the smallest additional costs are simply those which involve a switch in collection frequency or the addition of a single new material to an existing service which already includes most materials. The greatest change in costs are where households, which are currently receiving no, or very limited, recycling services, are moved to a 'best practice', and fully comprehensive, service. In the modelling these are the final changes to be made in terms of new recycling services rolled out;
2. The data and information around 'communal' dry recycling systems is limited. However, the approach to the modelling is, in essence, the same as that described above for 'doorstep' properties; and

3. In the model, it is assumed that Boroughs which currently operate co-mingled or source-separated collection schemes will continue with the same co-mingled or source-separated approaches.

3.4.2 Reuse Performance

The GLA has set a 2 per cent reuse target by 2020 and 3 per cent target by 2031. This equates to needing an additional 40,000tpa of new reuse capacity by 2012, ramping up to 120,000tpa by 2031.

3.4.3 Performance of Recycling and Reuse Centres (RRCs)

Recycling from RRCs will need to increase significantly such that the overall recycling targets can be met. We have modelled that improvements to RRCs will result in a recycling rate of 60% being reached by 2020, with a 70% rate being achieved by 2031. The 2020 target was set by Resource Futures in their analysis of RRCs in London.[16] Under the 'max GHG abatement' scenario (see Section 4.3), these increase to 70 and 80% respectively.

3.4.4 Recycling of Non-household Municipal Wastes

The impact of the Landfill Tax, and potential landfill bans being considered by Defra is such that it is likely that recycling rates for commercial wastes might become similar to those for households.

In 2008, the GLA published information relating to the proportion of commercial waste (70-75%) which might be recyclable within the hospitality, retail and office sub-sectors.[17] As this might be considered high for London as a whole, we have modelled commercial recycling rates as follows:

- Central Scenarios:
    - 2008 (current) – 5%;
    - 2015 – 40%;
    - 2020 – 50%;
    - 2031 – 60%.
- 'Max GHG abatement' Scenario (see Section 4.3):
    - 2015 – 20%;
    - 2020 – 55%; and
    - 2031 – 65%.

[16] Resource Futures (2008) London Reuse and Recycling Best Practice Guidance, RF Project no.: 376

[17] GLA (2008) Making waste work in London: The Mayors draft Business Waste Management Strategy", GLA, Feb 2008

3.4.5 Performance of On-the-Go Recycling Schemes

Increasing the number of on-the-go recycling facilities has been targeted as a way in which to improve recycling rates and enhance awareness of recycling in the London Boroughs. Performance levels of current schemes, however, are difficult to assess. Few direct comparisons can be made between systems due to variation in duration of the scheme, numbers and size of bins and materials collected.

In London there are currently three predominant collections systems:

- Paper only (mainly in areas where free papers are distributed);
- Comingled collection of paper, plastic bottles, cans and glass; and
- Separate collection of paper, plastic bottles, cans and glass.

Performance assumptions of future on-the-go recycling schemes are discussed in detail in Appendix 4. It should be noted here that we have made consistent assumptions for performance across each household scenario. These are based upon what we consider to be a conservative assumption, that 2 tonnes per annum will be captured and recycled per street bin. We have assumed that 30 bins per authority will be in place by 2015, 100 by 2020 and 200 by 2030.

3.4.6 Modelling of Residual Waste Treatment and Disposal

Currently, 75% of London's waste is deemed 'residual waste'. Around 3 million tonnes per annum therefore needs to be managed through options including landfill, incineration, MBT and gasification.

Waste flows to residual treatment processes are calculated by estimating captures of recyclables (via all methods of collection as discussed in Section 3.4.1) from total waste arisings and then assigning the remaining waste to different waste treatment processes. These tonnage inputs are then used to estimate the *total* costs and environmental impacts of residual waste management processes under each scenario. The composition of the waste entering the plant is also modelled to determine the level of energy produced and whether a process might qualify for Renewable Obligation Certificates (ROCs).

As detailed in Section 7.7, Eunomia's financial model estimates likely gate fees for waste treatment based upon capital and operating costs on a per tonne basis. The related residual treatment model, Atropos, uses a life-cycle analysis (LCA) approach to estimate the resulting environmental impacts from waste treatment processes, such as incineration, gasification, MBT and landfill.

3.4.6.1 Contribution of Residual Treatment to Recycling Rates

For each scenario modelled, recovery of materials at residual treatment facilities contributes to meeting recycling targets. This is especially important as not all Boroughs are likely to be able to achieve the Mayor's 45% recycling target by 2015 by non-residual recovery means alone.

3.4.6.2 Timing of New Residual Infrastructure

It should also be acknowledged that the *speed of change* will also be a factor for which assumptions might vary across scenarios. The scope of our analysis stretches out to 2031, and thus each scenario must have an associated time profile, which shows, for example, when treatment plants are constructed and become operational. As discussed in Section 9.7.2, this might have an impact on costs, depending upon assumptions relating to financial markets and future treatment of risk by funding institutions. We have also taken into consideration in our model what is achievable in terms of planning constraints for both 2020 and 2031.

3.4.6.3 Size of New Residual Facilities

The models used to provide evidence for the London Plan specified thermal facilities with a throughput of 100ktpa. In our model, we have therefore assumed that any new MBT and autoclave facilities will have throughputs of 120,000 to 150,000ktpa, such that any subsequent thermal treatment facilities (taking into consideration mass loss, materials recovery and rejects from pre-treatment) will process around 100ktpa of MSW.

See Appendix 5 for full details of these assumptions, and Appendix 9 for discussion of how the results might be affected if modeled using the Environment Agency's WRATE model.

3.5 Carbon Accounting and 'Monetisation' of GHG Emissions

HM Treasury's Green Book states that analysis of the costs of policy options should not be undertaken in isolation from quantification and monetisation of associated GHG emissions. To bring in an element of cost-benefit analysis (CBA) to the study, therefore, we have included modelling of the GHG emissions associated with each waste management scenario. As per previous work by Eunomia on behalf of the GLA, these emissions are monetised according to the new guidance recently been published by DECC.[18] See Sections 6.3 for further information of the approach used for this study.

[18] DECC (2009) *Carbon Valuation in UK Policy Appraisal: A Revised Approach*, July 2009

4.0 Determination of Scenarios

4.1 Principles for Scenario Selection

Scenarios included within the modelling for this study have selected based upon our understanding of:

- Best practice waste reduction, collection, recycling and treatment methods in the UK and other EU Member States;
- Practicality of implementing such techniques in different Boroughs, i.e. nature of housing stock has a key impact on some potential options; and
- Likely cost of these waste management techniques, based on real data.

The process of determination of the detail of these scenarios has adhered to a number of key principles and targets as follows:

- Recycling and composting rates of 45-60%;
- A high level of self-sufficiency (the existing London Plan sets out a goal for London to manage 50% of its own MSW by 2010, 75% by 2015 and 80% by 2020)[19];
- Minimisation of GHG emissions; and
- Maximisation of heat use from waste management facilities generating energy.

In each of the scenarios, it is assumed that recycling targets will be met 'as a whole' for London, i.e. as is currently the case, some Boroughs will perform better than others. It should also be noted, however, that the modelling for the study was not completely bound by these recycling targets. Varying the recycling targets, for example, was undertaken with some scenarios whereby the resulting effect was considered to have a greater environmental, or economic, benefit to London.

4.2 'Do Nothing New' Baseline Scenario

The 'Do Nothing New' scenario is used to measure the relative performance of the additional scenarios which will see a change in waste management in order to meet the targets. The scenario represents no change in the existing waste management collection systems and treatment / disposal routes. Under this definition 'existing' also includes facilities that have planning permission but have not yet come into operation. This includes, for example, the Belvedere incinerator. Housing and waste growth, however, does occur in this scenario.

[19] Greater London Authority (2008) The London Plan, Consolidated alterations since 2004 (Spatial Development Strategy for Greater London, February 2008

4.3 'Do Something' Scenarios

The 'Do Something' scenarios reflect a change in waste management practice in the following three main areas:

- Waste collection;
- Organic waste treatment; and
- Residual waste treatment.

As noted above, the abatement of GHG emissions is a clear focus of the Draft MWMS. Therefore, in addition to modelling scenarios to meet the targets set out in the Draft MWMS, we have developed a scenario whereby the abatement of GHG emissions is maximised.

4.3.1 Collection and Recycling Scenarios

Based on discussions with the GLA, Eunomia have modelled five scenarios as set out in Table 4-1. Further details around the assumptions on performance, and modelling of these scenarios, can be found in Appendix 4. The determination of the scenarios for consideration in this study, is *primarily* based upon differences in 'scheduled' household collection systems, although it is assumed for all the scenarios that reuse or capture of materials for recycling from the following 'non-scheduled' sources will also take place:

- Contracted, or third sector organisation (TSO), reuse collection and resale;
- Reuse and Recycling Centres (RRCs);
- Bring sites;
- Other recycling (including on-the-go); and
- Commercial wastes.

Assumptions relating to changes in the management of the non-scheduled household wastes are presented in Section 5.0. These assumptions are tested in Section 9.0 by way of sensitivity analysis, whereby increases in *non-scheduled household* recycling performance are limited.

It should be noted that the selection of scenarios has been undertaken to test the efficacy of different approaches to waste management in London. In reality, Boroughs would not be constrained by having to focus on one material, as local demographics play a big part in the nature of the services and contracts, often designed to meet LATS targets.

Table 4-1: Summary of Collection Scenarios

	Scenario Name	Description and Objectives	Order of Roll-out of New Services
1	'Do Nothing New'	Existing collection schemes remain in place. The performance of the schemes remains 'as is' today. This 'Do Nothing New' approach is required to measure the relative performance of the subsequent 'Do Something' scenarios	N/A
2	'Focus on Dry'	Meets (or exceeds) 45% recycling/composting rate by 2015, 50% by 2020 and 60% by 2031. Key aim is to test the financial and environmental outcomes from rolling out additional dry recycling collection first.	Collection of all dry materials (plastic bottles only) from doorstep and communal dwellings; Collection of food wastes from 'doorstep' dwellings only; Collection of food wastes from 'communal' dwellings only.
3	'Focus on Food'	Meets (or exceeds) 45% recycling/composting rate by 2015, 50% by 2020 and 60% by 2031. Key aim is to test the financial and environmental outcomes from rolling out additional organic collections first.	Food waste collection and treatment from doorstep and communal dwellings is prioritised; Collection of all dry materials (plastic bottles only) from 'doorstep' dwellings only; Collection of dry materials (plastic bottles only) from 'communal' dwellings only.
4	'Doorstep Only'	Meets (or exceeds) 45% recycling/composting rate by 2015, 50% by 2020 and 60% by 2031. Key aim is to test the financial and environmental outcomes from rolling out additional recycling services to 'easy to reach' doorstep properties, with the remaining residual waste from 'hard to reach' properties being sent to recovery via MBT processes which extract recyclables.	Collection of all dry materials (plastic bottles only) from 'doorstep' dwellings only; Collection of food wastes from 'doorstep' dwellings only; MBT plants to capture recyclables from residual waste stream from 'communal' based dwellings.
5	'Max GHG abatement'	Meets (or exceeds) 45% recycling/composting rate by 2015, 60% by 2020 and 70% by 2031 Collection costs are greater than for scenario 2, but savings will be made via the reduced amount of waste requiring residual treatment	'Order of roll-out' based on scenario 2, but will include collections of all dry materials (inc all plastics) and food from doorstep and communal dwellings;

Scheduled household collections that currently operate in the UK can collect a wide range of materials. In this study we focus on those which make up the significant proportion of the waste stream only. The key materials that are focused on are:

- Paper;
- Card;
- Metals (mostly cans etc);
- Glass;
- Plastics (mostly bottles, but also other mixed plastics); and
- Textiles.

Modelling the costs and performance of collection systems that might include mobile phones or household batteries, for example, is outside the scope of analysis.

4.3.2 Treatment of Green and Food (Organic) Wastes

With regard to modelling organic waste treatment, a number of factors are taken into consideration in the model. These include:

- The type of organic collection system in place (i.e. source separated food and garden, or co-mingled food with garden waste);
- The current and, likely, future mix of organic waste treatment infrastructure:
  - We assume, at the margin, that 50% of the collected food waste will go to anaerobic digestion facilities and 50% to in-vessel composting (IVC). Under the 'Max GHG abatement' scenario, however, all food waste is assumed to be managed by AD only;
  - All additional separated garden waste collected is assumed to be managed at open air windrow facilities;
- The GHG impacts of the various treatment processes.

It is also important to take into consideration the different potential configurations of AD facilities, which might come to market in London. For collection Scenarios 1 to 4, we have modelled costs and emissions for the following configurations:

- Use of gas engines to generate electricity only from biogas (60% of total food waste arisings);
- Use of gas engines to generate electricity and heat (CHP mode) from biogas (20% of total food waste arisings);
- Compression of biogas into vehicle fuel for local fleets (15% of total food waste arisings); and
- Upgrading and injection of biogas into the natural gas network (5% of total food waste arisings).

For Scenario 5, we have modelled only the AD configuration with the best associated GHG performance.

It is acknowledged here that AD can also be used to generate biogas (CH_4), which can be fed into a 'gas-shift' (or 'steam reforming') process for conversion to CO_2 and Hydrogen (H_2).[20] The latter can subsequently be used within stationery or vehicle-based fuel cells for energy generation at very high efficiencies. Whilst we have not modelled such processes here, we acknowledge that they have significant potential to deliver future GHG benefits, when the technologies become more commercially mature.

4.3.3 Residual Waste Treatment

The focus of this study is on the modelling of realistic scenarios, i.e. those which are being proposed in the current market. The following six residual treatment configurations have therefore included in the modelling of 'Do Something' scenarios:

a) MBT (bio-drying, e.g. Eco-Deco) with resulting low-biomass SRF sent for combustion (CHP mode);

b) MBT (bio-drying, e.g. Eco-Deco) with resulting low-biomass SRF sent for gasification (steam turbine in CHP mode);

c) MBT (bio-drying, e.g. Eco-Deco) with resulting low-biomass SRF sent for gasification (gas engine in CHP mode);

d) Autoclaving with high-biomass SRF to combustion (CHP mode) and plastics recovered for reprocessing;

e) Autoclaving with high-biomass SRF to gasification (steam turbine in CHP mode) and plastics recovered for reprocessing; and

f) Autoclaving with high-biomass SRF to gasification (gas engine in CHP mode) and plastics recovered for reprocessing.

The goal of the modelling will be to show differences in cost (and GHG emissions) between broad approaches to residual treatment. Based on the above technologies, we propose the following three residual scenarios:

- 'Do Nothing New' aside from what is already planned;
- 'New Tech (low-biomass / unrefined SRF)'[21] - all new facilities (i.e. those which do not yet have planning permission) are a combination of a), b) and c) above;

---

[20] In molten carbonate fuel cells (MCFCs) the 'gas-shift' and energy generation processes take place within the same physical unit

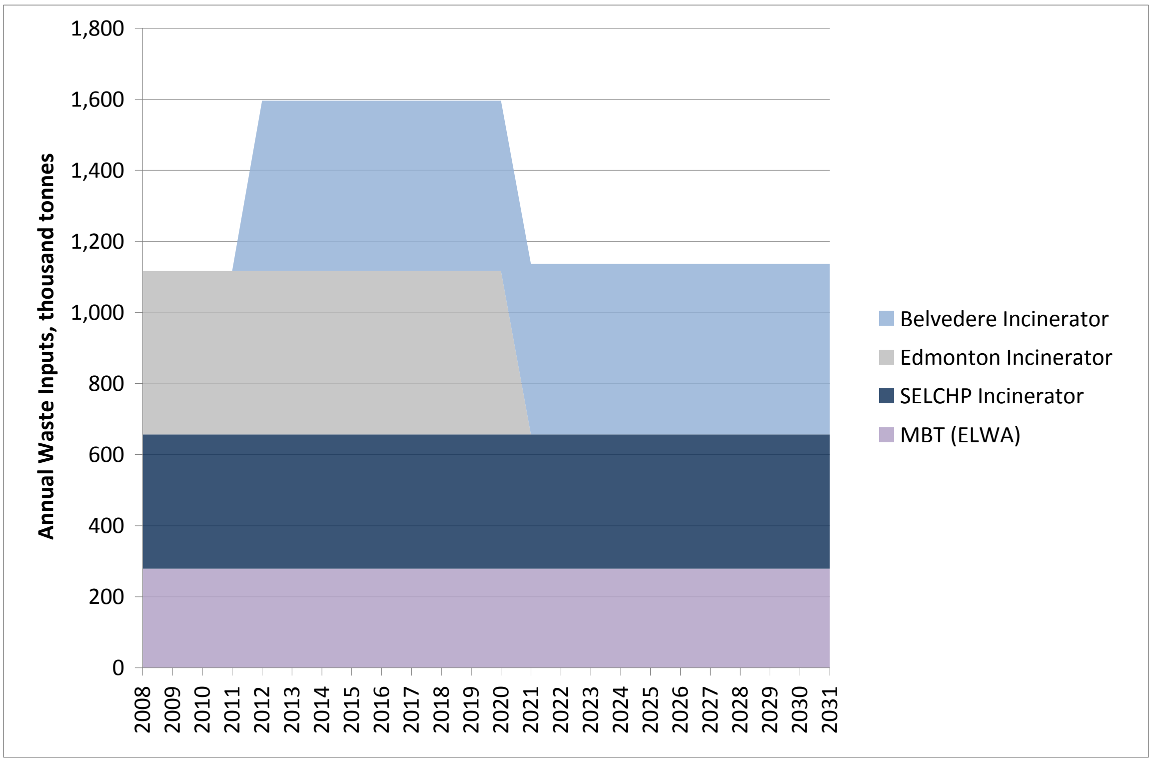
[21] 'Low biomass/Unrefined' refers to SRF that has not been refined to a high-quality with regard to achieving a high percentage biomass content to potentially maximise revenues from the Renewable Obligation. Such material is likely to contain significant proportions of plastic

- ‘New Tech (high-biomass / refined SRF)’[22] - all new facilities (i.e. those which do not yet have planning permission) are a combination of e), f) and g) above. This scenario is also used in the ‘max GHG abatement’ approach.

The quantity of residual waste that needs to be managed by new-build facilities is dependent upon both, the level of recycling, and existing residual waste treatment infrastructure. Although no new ‘conventional’ incineration capacity accepting untreated waste is envisaged beyond that currently in place or under construction, it should be acknowledged that this management route does form a part of each scenario modelled forward to 2031.

To aid understanding of the waste flows and costs in this study, the existing mix of residual waste treatment processes modelled in the ‘Do Nothing New’ baseline is shown in Figure 4-1. This is based on data reported by Boroughs using the WDF tool. It should be noted that the first sharp ‘kink’ in the graph is when the incinerator located in Belvedere is scheduled to begin operation in 2012/13 and the second ‘kink’ is when the Edmonton incinerator is scheduled to cease operation in 2020/21.

Figure 4-1 Residual Waste Management in ‘Do Nothing New’ Baseline



[22] ‘High biomass/refined’ refers to SRF that has been refined to a high-quality with regard to achieving a high percentage biomass content to potentially maximise revenues from the Renewable Obligation

For each scenario, we have assumed that all residual waste not treated by incineration will be split among the three treatment solutions. The market share afforded to each technology is shown in Table 4-2.

Table 4-2 Market Share of New Residual Technologies

New Techs	2015	2020	2031
New Tech ('low-biomass')			
a) MBT: SRF to Dedicated Combustion (CHP)	60%	40%	20%
b) MBT: SRF to Gasifier (Steam Turbine CHP)	40%	40%	20%
c) MBT: SRF to Gasifier (Gas Engine CHP)	0%	20%	60%
Total 'low-biomass'	*100%*	*100%*	*100%*
New Tech ('high-biomass')			
d) Auto: SRF to Dedicated Combustion (CHP)	60%	40%	20%
e) Auto: SRF to Gasifier (Steam Turbine CHP)	40%	40%	20%
f) Auto: SRF to Gasifier (Gas Engine CHP)	0%	20%	60%
Total 'high-biomass'	*100%*	*100%*	*100%*

4.4 Summary of Waste Management Scenarios

Based on the above discussions, we have modelled a total of 11 scenarios, as summarised in Table 4-3.

Table 4-3: Summary of Modelled Scenarios

Recycling Approach	Residual Approach	Scenario
'Do Nothing New' Baseline[1]		1
'Do Nothing New'	New Tech (low-biomass)	2
	New Tech (high-biomass)	3
'Focus on Dry'	'Do Nothing New'	4
	New Tech (low-biomass)	5
	New Tech (high-biomass)	6
'Focus on Food'	' Do Nothing New'	7
	New Tech (low-biomass)	8
	New Tech (high-biomass)	9
'Doorstep Only'[2]	New Tech (high-biomass)	10
'Max GHG Abatement'	New Tech (high-biomass) [3]	11

Notes:

1. Changes in costs and environmental performance are measured against the 'Do Nothing New' baseline scenario

2. Scenario 10 assumes only 'easy to reach' properties receive new kerbside collection systems, whilst residual waste, from doorstep and communal based (i.e. 'hard to reach') properties is sent to treatment facilities which recover relatively high levels of recyclables.

3. The residual approach which maximises GHG abatement is 'New Tech (high-biomass)'.

5.0 Resulting Scenario Waste Flows

The goal of this Section is to provide information as to how the overall recycling targets for each core year (2015, 2020 and 2031) are met for each of the 11 scenarios. It should be noted that the total number of households in London used in the modelling for 2008 is 3.3 million.

There are five collection scenarios modelled in this study. These are:

- ‘Do Nothing New’;
- Focus on Dry;
- Focus on Food;
- Doorstep Only; and
- ‘Max GHG Abatement’.

It should be noted that in Sections 5.1 to 5.4, reference is made to whether reaching a given recycling target in a given year is limited by estimated capture rates of dry or organic materials. This is designed not only show whether any additional change in collection systems could be achieved in each year, but also to show situations whereby households have already been switched to best practice (BP) schemes, and no further change is possible.

5.1 Change in Waste Management Practice (Focus on Dry)

Within this scenario the average performance of the three ‘best practice’ schemes increases from baseline levels (180kg/hhld/yr) to 253 kg/hhld/annum.[23] Table 5-1 shows that, notwithstanding this additional yield per household, when the focus is on dry materials, all households in London have to be switched to BP recycling schemes to meet the 45% target in 2015. The bottom row of the table shows that, in the collection model, none of the targets can be met through dry recycling alone. If the performance of the various schemes was improved above *realistic* best practice yields – through design or communication – it is possible the targets could be met. This issue is considered by modelling the ‘max GHG abatement’ scenario.

[23] ‘Best practice’ dry recycling schemes are described in Appendix 3.

Table 5-1: Change in Coverage of Best Practice (BP) Dry Recycling Schemes in London (Focus on Dry)

Parameter	Max Possible Change (000s)	2015 (000s)	2020 (000s)	2031 (000s)
Total Households Switched to BP Kerbside Sort (Doorstep)	645	645	0	0
Total Households Switched to BP Comingled (Doorstep)	1,656	1,656	0	0
Change in Bring Collections (Communal)	238	238	0	0
Target Limited by collection of Dry materials?[1]	n/a	Yes	Yes	Yes
Notes: 1. If 'Yes' this indicates that not enough yield of recyclables from DRY schemes can be delivered to meet the recycling targets in that year				

Under this scenario (note, residual waste management shifts to new technologies with low biomass / unrefined SRF), in order to increase recycling in London, by 20% by 2015, a significant shift in the management of organic wastes is also required. Table 5-2 below shows that, firstly, relevant additional doorstep households receive garden waste services (these are the cheapest switches in terms of financial costs), followed by a significant increase in the number of doorstep and communal households receiving a kitchen waste collection service, by 2015.

The maximum possible change has occurred under this scenario by 2015. Thus no further roll out of services is possible to help meet the 2020 and 2031 targets.

Table 5-2: Change in Coverage of Best Practice (BP) Organic waste Schemes in London (Focus on Dry)

Parameter	Max Possible Change (000s)	2015 (000s)	2020 (000s)	2031 (000s)	Remaining without Scheme (000s)
Total Additional Households Receiving a Garden Waste Collection Service (Doorstep)	494	436	0	0	0
Total Additional Households Receiving a Kitchen Waste Collection Service (Doorstep)	1,280	1,228	0	0	0
Total Additional Households Receiving a Kitchen Waste Collection Service (Communal)	1,016	1,016	0	0	0
Target Limited by collection of Biowaste?[1]	n/a	No	No	Yes	n/a
Notes: 1. If Yes this indicates that not enough yield of biowaste can be delivered from the schemes, over and above the DRY recycling collections, to meet the recycling targets in that year					

Table 5-3 shows the collection of all materials from kerbside schemes under the 'focus on dry' scenario. To achieve the initial target of 45% in 2015, a significant increase in the performance of all dry recyclable collection systems, across all housing types, is required to increase the average yield to 234 kg/hhld/yr. Given that the maximum outliers for doorstep only systems, in London, are currently around 220, and communal properties are around 120, the performance would have to increase to the same levels as that seen in 'prospering small towns' and 'prospering Southern England' (currently around 300 kg/hhld/yr).[24] Clearly it may be optimistic to assume the required changes in performance. In the longer term (out to 2031) the barriers to higher recycling rates might diminish, hence this conservatism in reaching higher captures in the later years, may not be warranted.

[24] Icaro Consulting (2009) *Analysis of kerbside dry recycling performance in England 2007/08 (WRAP Project EVA034-087),* Summary Report

Table 5-3: Breakdown of Recycling Performance (Focus on Dry)

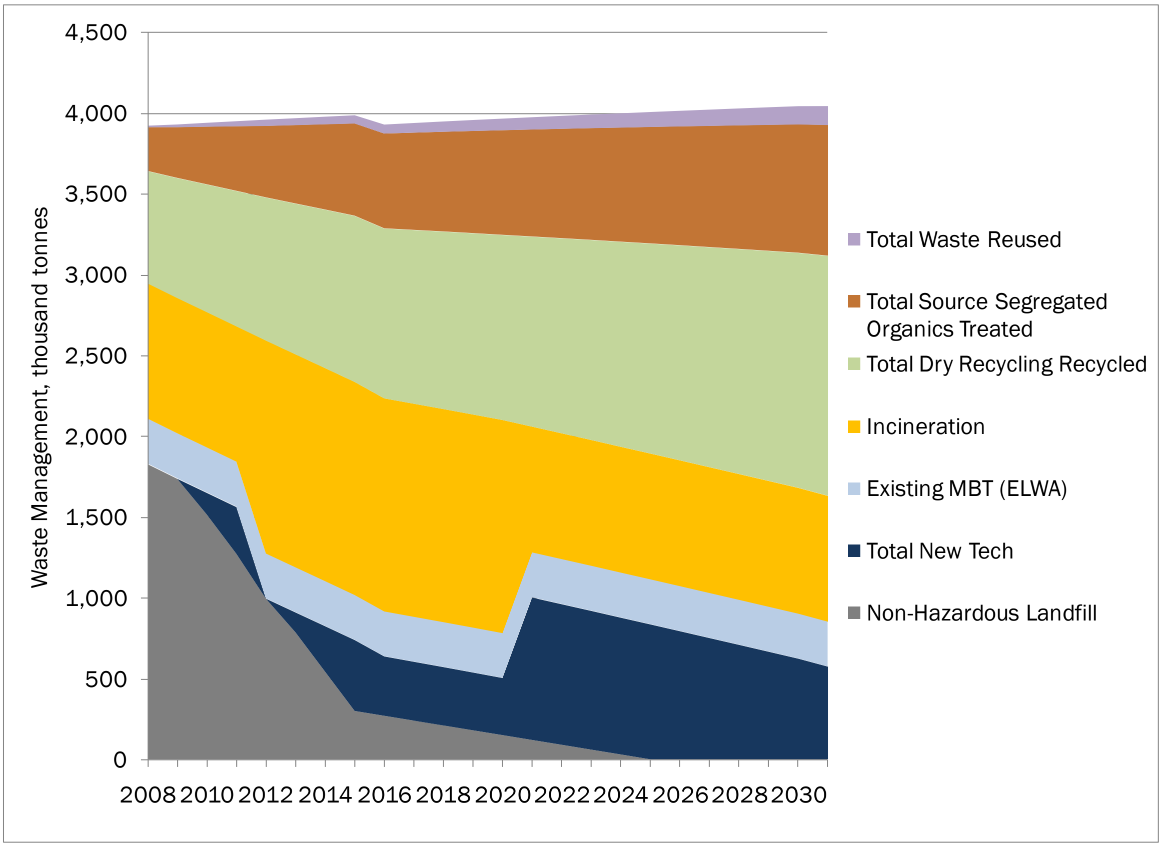
Parameter		2008	2015	2020	2031
Scheduled Household Collections	Hhld Kerbside Dry Recycling	11%	19%	20%	23%
	kg/hhld/yr	144	229	235	265
	Hhld Kerbside Biowaste Composting	5%	11%	12%	15%
	kg/hhld/yr	94	132	140	166
	Total Kerbside Recycling / Composting	**16%**	**30%**	**33%**	**38%**
Other Recycling	Reuse	0%	1%	2%	3%
	Recycling & Reuse Centres	5%	6%	6%	8%
	Bring	1.4%	1.4%	1.4%	1.5%
	Commercial	1%	5%	7%	8%
	Other Recycling / Composting[1]	1.1%	1.1%	1.1%	1.2%
	Recycling from Residual Processes	0.0%	0.7%	0.6%	1.3%
	Total Non-kerbside Recycling / Composting	**9%**	**16%**	**18%**	**23%**
Total Recycling in London		**25%**	**45%**	**50%**	**60%**

Notes:

1. Other Recycling / Composting includes materials collected from on-the-go / on-street recycling, green waste from parks and other methods of capture

Figure 5-1 below shows the management of London's waste under the 'focus on dry' collection scenario. The slight reduction in total waste arisings in 2015 reflects a waste prevention effect resulting from the roll-out of new kitchen waste collection schemes. This effect is described in detail in Appendix 3. Figure 5-1 also shows no change in current baseline residual waste management, other than the Belvedere incinerator coming on-line in 2011/2 and the Edmonton incinerator assumed to be decommissioned in 2020. The rise and subsequent fall of treatment capacity of new technologies (New Tech) in 2012/13 reflects current planned new facilities in London, which may then represent over-capacity should the Mayor's recycling targets be met, i.e. there will be less MSW available for residual treatment.

Figure 5-1 London's Waste Management under 'Focus on Dry' Scenario



Note: The chart represents inputs to primary waste treatments / reprocessing routes, and does not include secondary reprocessing.

5.2 Change in Waste Management Practice (Focus on Food)

Under the 'Focus on Food' scenario, firstly, the coverage of garden waste services to *doorstep only* households, where there is none currently operating, is extended. This is followed by increasing the coverage of existing kitchen waste collection systems across Boroughs (comingled or separate) and finally rolling out additional separate collections of kitchen waste across London Boroughs, where none currently exists. This is undertaken in a cost effective manner, i.e. the cheapest schemes are implemented first (for both doorstep and communal properties). When the maximum change has occurred, if required, additional dry collection systems are rolled out to meet the targets.

Under this scenario the yields achievable from doorstep schemes increase over time to reach current best practice performance. The current achievable yields of kitchen waste from *communal* properties are uncertain, but performance is likely to be low. We have, therefore, also modelled an increase in performance from these systems over time. Table 5-4 shows that to meet the 2015 target, a garden or kitchen waste collection service needs to be rolled out to all doorstep households not already receiving one. Furthermore, *all* communal properties must also receive a kitchen waste collection.

Table 5-4: Change in Coverage of Best Practice (BP) Organic Waste Schemes in London (Focus on Food)

Parameter	Max Possible Change (000s)	2015 (000s)	2020 (000s)	2031 (000s)	Remaining without Scheme (000s)
Total Additional Households Receiving a Garden Waste Collection Service (Doorstep)	494	494	0	0	0
Total Additional Households Receiving a Kitchen Waste Collection Service (Doorstep)	1,280	1,280	0	0	0
Total Additional Households Receiving a Kitchen Waste Collection Service (Communal)	1,016	1,016	0	0	0
Target Limited by collection of Biowaste?	n/a	Yes	No	Yes	n/a

Notes:

1. If Yes this indicates that not enough yield of biowaste can be delivered from the various schemes to meet the recycling targets in that year.

The analysis in Table 5-4 shows that that not enough tonnage can be captured from organic waste collection schemes alone to meet the targets in either 2015 or 2031. Consequently, to meet the 2015 target, significant additional recycling from ‘dry material’ schemes is required as shown in Table 5-5, in fact to the same extent as under the ‘focus on dry’ scenario. The main difference between these two scenarios, therefore, is in the order of roll-out of services to 2015, which is shown in more detail in Appendix 4.

Table 5-5 Change in Coverage of Best Practice (BP) Dry Recycling Schemes in London (Focus on Food)

Parameter	Max Possible Change (000s)	2015 (000s)	2020 (000s)	2031 (000s)
Total Households Switched to BP Kerbside Sort (Doorstep)	645	645	0	0
Total Households Switched to BP Comingled (Doorstep)	1,656	1,656	0	0
Change in Bring Collections (Communal)	238	238	0	0
Target Limited by collection of Dry materials?[1]	n/a	Yes	Yes	Yes
Notes: 1. If 'Yes' this indicates that not enough yield of recyclables from DRY schemes can be delivered to meet the recycling targets in that year				

As can be seen in Table 5-6, significant increases in both dry recycling and organic waste collection are required to meet the Mayor's targets. In all years shown, the percentage recycling rates are, in fact, the same as those under the 'focus on dry' scenario (see Table 5-3).[25] This indicates that, at the margin, the focus needs to be on both dry materials *and* organic wastes for London to meet *all* the targets set out in the draft MWMS.

[25] The main difference between these two scenarios, therefore, is in the order of roll-out of services to 2015, which is shown in more detail in Appendix 4.

Table 5-6: Breakdown of Recycling Performance (Focus on Food)

Parameter		2008	2015	2020	2031
Scheduled Household Collections	Hhld Kerbside Dry Recycling	11%	19%	20%	23%
	kg/hhld/yr	144	229	235	265
	Hhld Kerbside Biowaste Composting	5%	11%	12%	15%
	kg/hhld/yr	94	132	140	166
	Total Kerbside Recycling / Composting	**16%**	**30%**	**33%**	**38%**
Other Recycling	Reuse	0%	1%	2%	3%
	Recycling & Reuse Centres	5%	6%	6%	8%
	Bring	1.4%	1.4%	1.4%	1.5%
	Commercial	1%	5%	7%	8%
	Other Recycling / Composting[1]	1.1%	1.1%	1.1%	1.2%
	Recycling from Residual Processes	0.0%	0.7%	0.6%	1.3%
	Total Non-kerbside Recycling / Composting	**9%**	**16%**	**18%**	**23%**
Total Recycling in London		**25%**	**45%**	**50%**	**60%**

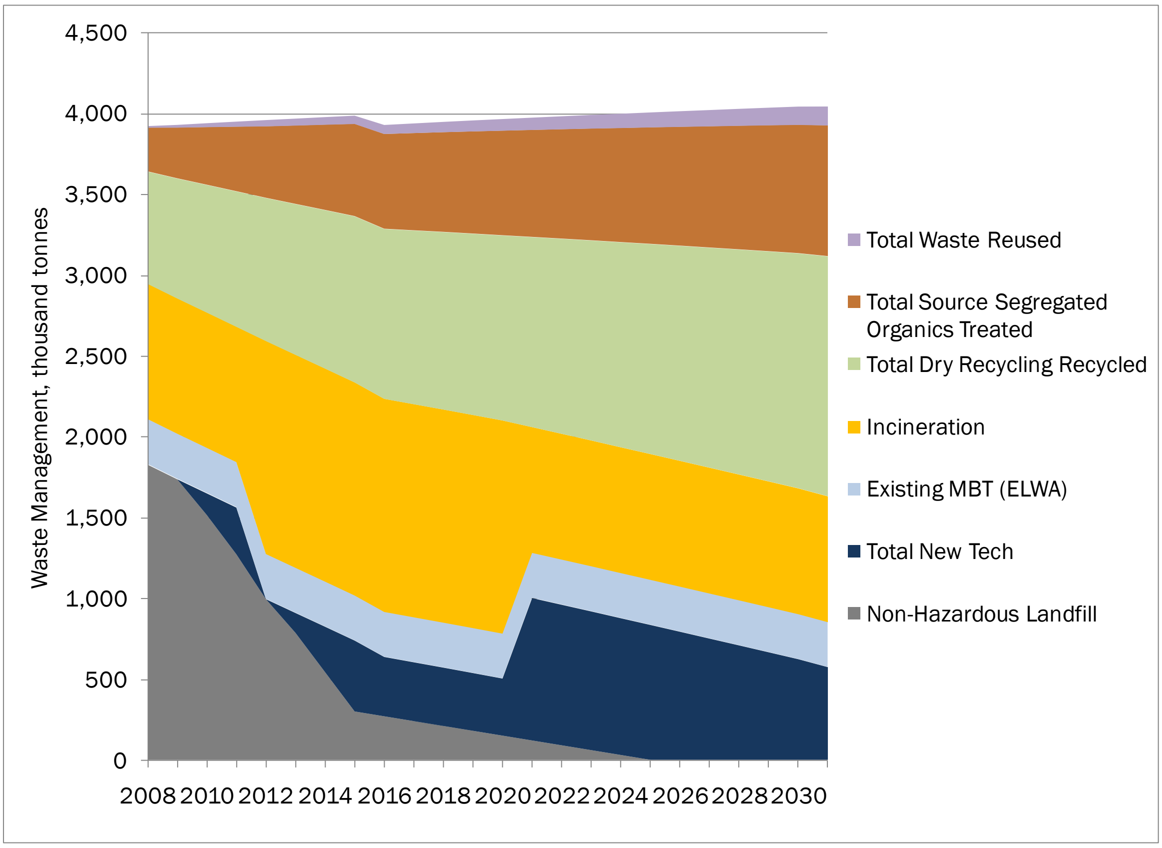
Notes:

1. Other Recycling / Composting includes materials collected from on-the-go / on-street recycling, green waste from parks and other methods of capture

Figure 5-2 below shows the split of waste management activities in London under the 'focus on food' collection scenario. As mentioned above, this is the same to that shown in Figure 5-1 above under the 'focus on dry' scenario, and the main difference between these two scenarios, therefore, is in the order of roll-out of services to 2015, which is shown in more detail in Appendix 4.

Again, one can see the effect of waste prevention from the introduction of widespread food waste collections in 2015.[26] It should also again be noted that the rise and subsequent fall in 2012/13 of treatment capacity using new technologies (New Tech) reflects current planned new facilities in London, which may then represent over-capacity should the Mayor's recycling targets be met, i.e. there will be less MSW available for residual treatment.

Figure 5-2 London's Waste Management under 'Focus on Food' Scenario



Note: The chart represents inputs to primary waste treatments / reprocessing routes, and does not include secondary reprocessing.

5.3 Change in Waste Management Practice (Doorstep Only)

Under this collection scenario the order of roll out of collection systems is as follows:

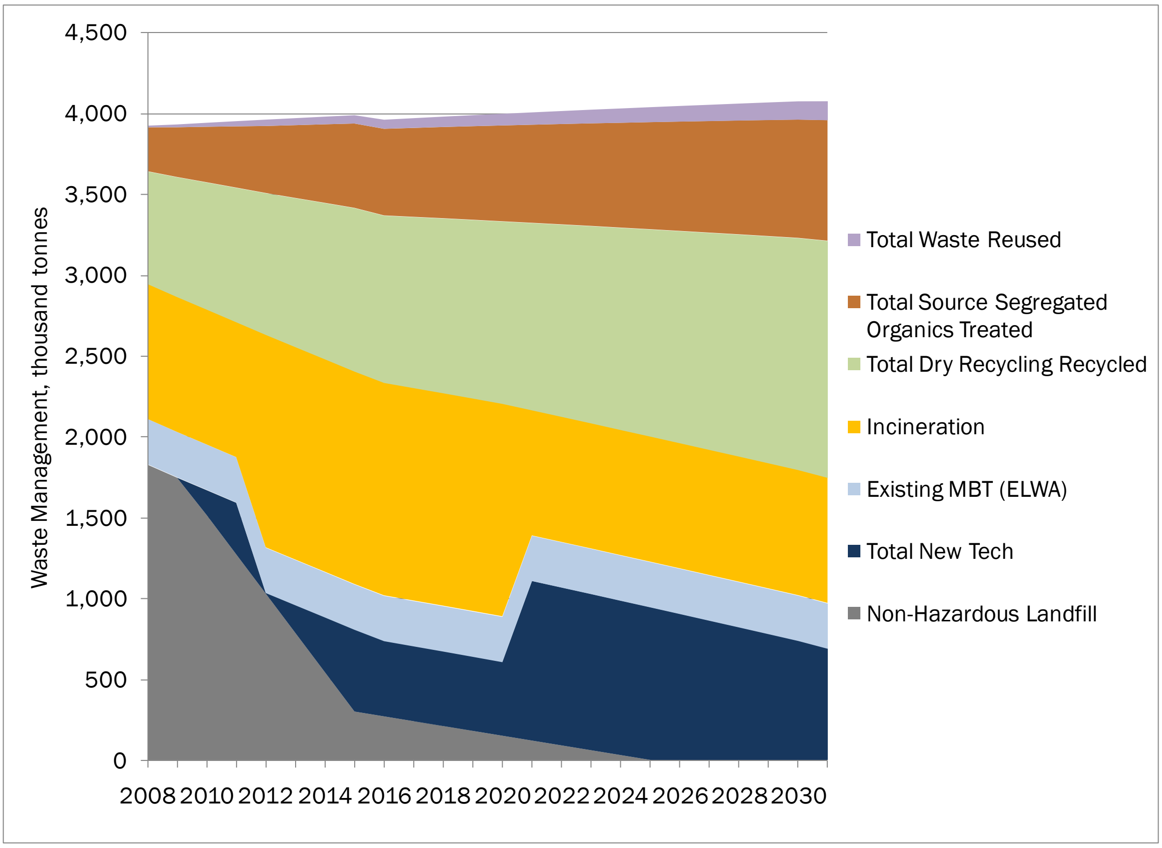
[26] See Appendix 3 for discussion of this effect

- Dry recycling schemes, with two or more materials currently collected, are extended to all households, whilst doorstep properties are switched to best performing systems; and
- Organic collection schemes are both extended and for doorstep properties, are switched to best performing systems.

Under this scenario, to meet the 2015 target, all changes in dry recycling and organics services must happen by 2015.

This waste flows under this scenario are presented in Figure 5-3. Again, it should be acknowledged that the rise and subsequent fall in 2012/13 of treatment capacity using new technologies (New Tech) reflects current planned new facilities in London, which may then represent over-capacity should the Mayor's recycling targets be met, i.e. there will be less MSW available for residual treatment.

Figure 5-3 London's Waste Management under 'Doorstep Only' Scenario



Note: The chart represents inputs to primary waste treatments / reprocessing routes, and does not include secondary reprocessing.

Table 5-7 shows that when no further increase in kerbside recycling from communal properties occurs, and all corresponding waste is diverted to MBT processes, not enough material can be recovered to meet the 45%, 50% or 60% target in 2015, 2020 and 2031 respectively.

Table 5-7: Breakdown of Recycling Performance (Doorstep Only)

Parameter		2008	2015	2020	2031
Scheduled Household Collections	Hhld Kerbside Dry Recycling	11%	18%	20%	22%
	kg/hhld/yr	144	223	229	258
	Hhld Kerbside Biowaste Composting	5%	9%	11%	13%
	kg/hhld/yr	94	117	123	148
	Total Kerbside Recycling / Composting	**16%**	**28%**	**30%**	**35%**
Other Recycling	Reuse	0%	1%	2%	3%
	Recycling & Reuse Centres	5%	6%	6%	8%
	Bring	1.4%	1.4%	1.4%	1.5%
	Commercial	1%	5%	7%	8%
	Other Recycling / Composting[1]	1.1%	1.1%	1.1%	1.2%
	Recycling from Residual Processes	0.0%	0.9%	0.8%	1.6%
	Total Non-kerbside Recycling / Composting	**9%**	**16%**	**18%**	**23%**
Total Recycling in London		**25%**	**44%**	**48%**	**58%**

Notes:

1. Other Recycling / Composting includes materials collected from on-the-go / on-street recycling, green waste from parks and other methods of capture

5.4 Change in Waste Management Practice (Max GHG Abatement)

As for the 'focus on dry' scenario, under the 'max GHG abatement' scenario, the order of roll-out under the 'max GHG abatement' scenario commences with new collection services for dry recyclables, followed by those for organic wastes. Again, as for the 'focus on dry' scenario there is not enough yield from collections to meet the Mayor's targets, despite the assumed increased performance, so the change in dry materials collection systems is the same as that shown above in Table 5-1. Relative to all other scenarios, however, there are additional increases in recycling from both RRCs and commercial enterprises (around an additional 1% each by 2031), and assumed increases in performance from existing kerbside collection systems.

The additional biowaste schemes required to further increase recycling in 2020 and 2031 are summarized in Table 5-8. The increased performance of the existing collection systems (both dry and biowaste) results in the case where the maximum recycling targets can be met without having to roll out food waste collections to all properties in 2015. However, all households must receive a food waste collection service by 2020 to meet the targets in this year and in 2031.

Table 5-8: Change in Coverage of Best Practice (BP) Biowaste Schemes in London (Max GHG Abatement)

Parameter	Max Possible Change (000s)	2015 (000s)	2020 (000s)	2031 (000s)	Remaining without Scheme (000s)
Total Additional Households Receiving a Garden Waste Collection Service (Doorstep)	494	434	60	0	0
Total Additional Households Receiving a Kitchen Waste Collection Service (Doorstep)	1,280	973	306	0	0
Total Additional Households Receiving a Kitchen Waste Collection Service (Communal)	1,016	0	1,016	0	0
Target Limited by collection of Biowaste?[1]	n/a	No	Yes	Yes	n/a

Notes:

1. If TRUE this indicates that not enough yield of biowaste can be delivered from the schemes, above the DRY recycling collections, to meet the recycling targets in that year.

Table 5-9 shows the resultant recycling achieved under the Max GHG scenario.

Table 5-9: All Materials Collection (Max GHG)

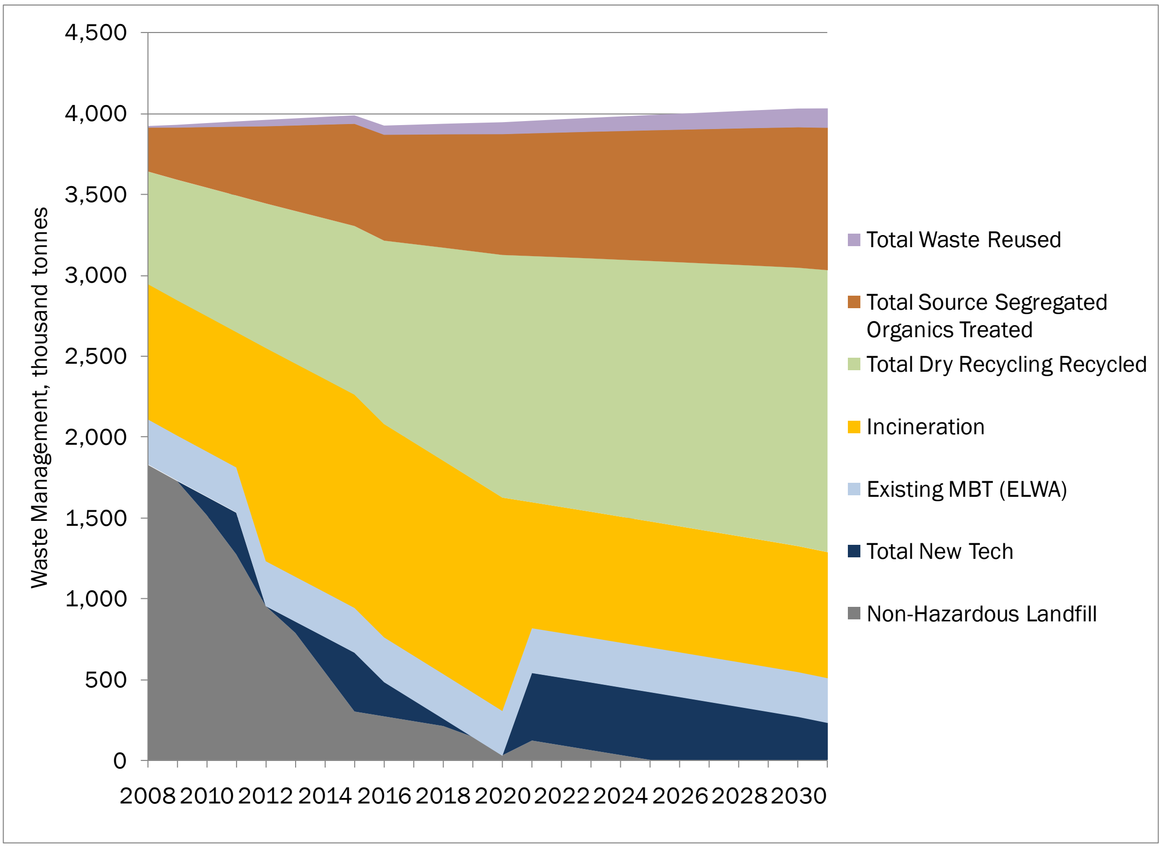
Parameter		2008	2015	2020	2031
Scheduled Household Collections	Hhld Kerbside Dry Recycling	11%	19%	24%	27%
	kg/hhld/yr	144	229	275	309
	Hhld Kerbside Biowaste Composting	5%	10%	13%	16%
	kg/hhld/yr	94	119	155	177
	Total Kerbside Recycling / Composting	**16%**	**28%**	**37%**	**43%**
Other Recycling	Reuse	0%	1%	2%	3%
	Recycling & Reuse Centres	5%	7%	8%	9%
	Bring	1.4%	1.4%	1.4%	1.5%
	Commercial	1%	5%	8%	9%
	Other Recycling / Composting[1]	1.1%	1.1%	1.1%	1.2%
	Recycling from Residual Processes	0.0%	0.7%	0.0%	0.6%
	Total Non-kerbside Recycling / Composting	**9%**	**17%**	**20%**	**24%**
Total Recycling in London		**25%**	**45%**	**57%**	**67%**

Notes:

1. Other Recycling / Composting includes materials collected from on-the-go / on-street recycling, green waste from parks and other methods of capture

Figure 5-4 shows that, compared to the other four collection scenarios which meet the 60% target by 2031 (see Figure 5-1, for example), the additional waste available for residual treatment is significantly lower under this scenario. Furthermore, in 2020 the tonnage landfilled falls very close to zero. These results indicate that the achievement of a 57% recycling rate in 2020 would most likely result in an over capacity of residual waste treatment, in addition to potential overcapacity in 2012/13, as per the other four scenarios.

Figure 5-4 London's Waste Management under 'Max GHG Abatement' Scenario



Note: The chart represents inputs to primary waste treatments / reprocessing routes, and does not include secondary reprocessing.

5.5 Summary of Recycling Rates Achieved

The recycling rates achieved by each scenario for each year are shown in Table 5-10. It should be noted that the targets set out in the Mayor's Draft MWMS are met, or exceeded, in all cases, except in 2031, under the 'focus on dry' and 'focus on food' scenarios when no additional residual treatment is procured, and in 2020 and 2031 under the 'doorstep only' scenario (Scenario 10). The lower performance of these scenarios is the result of insufficient tonnages being recovered via residual treatment processes to make up for a lower level of collection from 'communal' households.

Under the 'Do Nothing New' scenario (Scenario 1), recycling rates increase from current levels to 26% as a result of the assumed increase in housing stock in the baseline, enabling more waste to be recovered in total.

The difference between the 2031 recycling rates achieved under Scenarios 2 and 3, is the result of varying levels of materials recovery from different residual treatment processes. These total levels of recycling (i.e. 28% and 31%) show that focusing solely on the development of new residual treatment facilities will not deliver the recycling targets stated in the Mayor's Draft MWMS.

The maximum MSW recycling rates achievable in London (under the assumptions used in this study) appear to be 57% in 2020 and 67% in 2031, i.e. those under the 'Max GHG Abatement' scenario.

It should be noted, however, that the further forward in time that modeling of this nature is undertaken, the greater the associated uncertainty. As such, these figures should not be taken as absolute limits. Other factors such as changing waste composition or design for recyclability could drive recycling rates higher in the longer term.

Table 5-10 Recycling Rates Achieved for all Scenarios

Recycling Approach	Residual Approach	Scenario	2008	2015	2020	2031
'Do Nothing New' Baseline		1	25%	25%	25%	26%
'Do Nothing New'	New Tech (unrefined)	2	25%	26%	26%	28%
	New Tech (high-biomass)	3	25%	28%	28%	31%
'Focus on Dry'	'Do Nothing New'	4	25%	45%	50%	59%
	New Tech (unrefined)	5	25%	45%	50%	60%
	New Tech (high-biomass)	6	25%	45%	50%	60%
'Focus on Food'	' Do Nothing New'	7	25%	45%	50%	59%
	New Tech (unrefined)	8	25%	45%	50%	60%
	New Tech (high-biomass)	9	25%	45%	50%	60%
'Doorstep Only'	New Tech (high-biomass)	10	25%	45%	49%	58%
'Max GHG Abatement'	New Tech (high-biomass)	11	25%	45%	57%	67%

5.6 Indicative New Waste Infrastructure Required

To understand the likely additional costs London faces to meet the recycling targets within the Mayor's Draft MWMS, it is useful provide analysis of the associated infrastructure which would be required to deliver upon the future waste flows detailed above for each scenario. This potential infrastructure is detailed in Table 5-11 to Table 5-14.

The key points to note from the data provided in Table 5-11 to Table 5-14 include:

- The difference in waste infrastructure required between the 'focus on dry' and 'focus on food' scenarios is negligible;
- Under the 'doorstep only' scenario, less overall dry recycling and organic waste management infrastructure is required, along with a greater amount of 'new tech' residual treatment capacity to manage additional residual waste from 'communal' based households; and
- Under the 'max GHG abatement' scenario, the requirement for dry recycling and garden waste infrastructure increases. At the same time, as AD is considered to maximise GHG abatement for the treatment of food waste, relate capacity increases significantly and no additional IVC capacity is required.

Importantly, it should be noted, however, that the information provided in Table 5-11 to Table 5-14 is indicative only, and is based upon modelling of theoretical scenarios designed to demonstrate different approaches to waste management in London. In reality, a mix of approaches is likely to be appropriate, and therefore actual infrastructure might be somewhat different to that presented for any scenario modelled for this study. It should therefore also be emphasised that this data should not be used in any way to apportion related infrastructure across London Boroughs.

Table 5-11: New Infrastructure Capacity required under 'Focus on Dry' Scenario (000 tonnes)

Potential Infrastructure	2015	2020	2031
Transfer Stations (for source separated dry recyclables)	472	559	763
MRFs	212	256	336
Open Air Windrow	48	62	124
IVC	114	147	196
AD	114	147	193
New Techs	297	224	556

Table 5-12: New Infrastructure Capacity required under 'Focus on Food' Scenario (000 tonnes)

Potential Infrastructure	2015	2020	2031
Transfer Stations (for source separated dry recyclables)	452	541	744
MRFs	210	256	336
Open Air Windrow	52	67	131
IVC	121	152	203
AD	121	153	200
New Techs	297	222	554

Table 5-13: New Infrastructure Capacity required under 'Doorstep Only' Scenario (000 tonnes)

Potential Infrastructure	2015	2020	2031
Transfer Stations (for source separated dry recyclables)	452	538	740
MRFs	211	254	335
Open Air Windrow	52	68	132
IVC	96	124	170
AD	96	124	167
New Techs	348	311	652

Table 5-14: New Infrastructure Capacity required under 'Max GHG Abatement' Scenario (000 tonnes)

Potential Infrastructure	2015	2020	2031
Transfer Stations (for source separated dry recyclables)	486	777	984
MRFs	212	360	457
Open Air Windrow	82	120	168
IVC	0	0	0
AD	179	348	428
New Techs	297	0	235

6.0 Environmental and Technology Performance Assumptions

This section outlines our assumptions relating to environmental parameters and technology performance within the study. It should be noted that this information is in summary form only, and that Appendix 8 provides detailed background information to each of the assumptions listed in Section 6.1. In Section 6.2, we provide analysis of how some of these assumptions compare with those published by DECC and Defra, whilst in Section 6.3 we summarise our approach to monetising CO_2 emissions.

It should be noted that this study considers only the climate change implications, i.e. GHG emissions, of managing waste, although we acknowledge that other pollution impacts will also result from its treatment. In terms of residual waste treatment, our environmental model, Atropos, accounts for both the direct GHGs that occur as a result of the treatment process itself, and the avoided GHG emissions resulting from any energy generated or materials recovered for recycling.

The majority of the assumptions summarised in Section 6.1 and detailed in Appendix 8 are based upon those developed by Eunomia in partnership with the UK Committee on Climate Change for a study to support the UK Climate Change Bill.[27] These assumptions were subsequently refined further for a study on behalf of Defra, Scottish Government, WAG and DOENI (funded by WRAP), which modelled the potential impact of landfill bans in the UK.[28]

6.1 Summary of Key Assumptions

The key assumptions used in the modelling for this study are summarised in Table 6-1 to Table 6-6.

[27] Eunomia (2008) Development of Marginal Abatement Cost Curves for the Waste Sector, Report on behalf of the Committee on Climate Change, December 2008

[28] Eunomia (2010) Landfill Bans: Feasibility Research, Eunomia on behalf of WRAP, March 2010

Table 6-1: Key Assumptions relating to Wastes in Landfill

Parameter	Assumption
Proportion of methane captured (untreated waste)	50%
Proportion of methane captured (waste pre-treated at MBT facility)	0%
Proportion of captured methane used for energy generation	60%
Proportion of captured methane that is flared	40%
Efficiency of electricity generation, landfill gas engine	35%
Rate of oxidation of methane within the landfill cover (untreated waste)	10%
Rate of oxidation of methane within the landfill cover (pre-treated waste)	90%

Table 6-2: Key Assumptions relating to Incineration

Parameter	Assumption
Gross electrical generation efficiency (electricity only)	27%
Gross electrical efficiency (CHP mode)	10%
Gross heat efficiency (CHP mode)	56%
Recycling of bottom ash	50%
Recovery rate for ferrous metals	70%
Recovery rate for non-ferrous metals	30%

Table 6-3: Key Assumptions relating to Gasification (processing SRF)

Process	Assumption[1]
Gross electrical generation efficiency using a steam turbine operating in CHP mode	10%
Gross heat generation efficiency using a steam turbine operating in CHP mode	56%
Gross electrical generation efficiency using a gas engine operating in CHP mode	40%
Gross heat generation efficiency using a gas engine operating in CHP mode	45%
Notes: 1. The efficiencies presented here do not include consideration of either a heat load factor or electrical 'parasitic load', which are discussed further in Appendix 8. Hence the overall 'net' efficiency modelled for gas engines, for example, is lower than the 85% (40% + 45%) indicated.	

Table 6-4: Key Assumptions for Avoided Emissions from Reuse / Recycling

Parameter	Avoided Emissions (tCO_2/t Material Recycled)
Reuse	0
Paper and card	0.62
Dense plastic	1.40
Plastic Film	1.47
Mixed Glass	0.31
Steel	1.34
Aluminium	9.17
Wood	0.001
Textiles	3.03

Table 6-5: Key Assumptions for Emissions from Organic Waste Treatment

Process	Emissions (tCO_2/t Waste Treated)
AD: on-site biogas use (electricity only)	-0.05
AD: on-site biogas use (CHP only)	-0.07
AD: compressed biogas used in vehicles	-0.19
AD: biogas injected to gas grid	-0.07
In-vessel composting	0.03
Open-air windrow composting	0.04

It should be noted that the GHG emissions from residual waste treatment processes vary according to the input composition of MSW. In our scenario modelling, we have modelled three core residual compositions. We use a ‘medium’ recycling composition for the intermediate target years to reflect around 45% recycling and a ‘high’ recycling composition to reflect a 60% rate being achieved in 2031. Furthermore, there are two likely methods of achieving these levels of recycling, by focusing on capture of dry materials or focusing on capture of food wastes.

Table 6-6 provides a summary of the impacts of different residual treatment technologies when processing these different waste compositions. Of particular note is the better performance of scenarios which include an autoclave (or MHT) facility rather than an MBT (bio-drying) facility, producing an SRF for processing via combustion or gasification. This is due to the greater assumed percentage of non-fossil carbon within SRF from autoclave facilities (70%) when compared to the assumption for MBT (bio-drying) facilities (46%). As mentioned above, further information relating to all performance assumptions for each treatment technology is provided in Appendix 8.

Table 6-6: Key Assumptions for Emissions from Residual Waste Treatment

Treatment Scenario	Emissions (tCO_2/t Waste Treated)		
	Med (dry)	Med (org)	High
Incineration ('Electricity Only' Mode)	0.12	0.16	0.25
a) MBT (bio-drying) with resulting low-biomass SRF sent for combustion (CHP mode)	0.11	0.12	0.17
b) MBT (bio-drying) with resulting low-biomass SRF sent for gasification (steam turbine in CHP mode)	0.16	0.18	0.25
c) MBT (bio-drying) with resulting low-biomass SRF sent for gasification (gas engine in CHP mode)	0.04	0.03	0.08
d) Autoclaving with high-biomass SRF to combustion (CHP mode) and plastics recovered for reprocessing	-0.08	-0.11	-0.05
e) Autoclaving with high-biomass SRF to gasification (steam turbine in CHP mode) and plastics recovered for reprocessing	-0.05	-0.07	-0.02
f) Autoclaving with high-biomass SRF to gasification (gas engine in CHP mode) and plastics recovered for reprocessing	-0.17	-0.20	-0.15

6.2 Comparison with DECC Company Reporting Guidelines

Information regarding the GHG impacts of waste management methods can also be found in the Defra / DECC Guidelines for Company Reporting.[29] This data is based on that presented in the Impact Assessment produced by Defra as part of the Waste Strategy for England 2007, with some additional information provided by WRAP in 2009.[30] The Impact Assessment data was, in turn, based on analysis provided by ERM for Defra in 2006 and the previously cited International Review of the Impacts of Recycling produced by WRAP.[31]

---

[29] AEA (2009) Guidelines to Defra / DECC's Conversion Factors for Company Reporting, Report for Defra / DECC

[30] Defra (2007) Waste Strategy for England 2007: Annex A – Impact Assessment

[31] ERM (2006) Carbon Balances and Energy Impacts of the Management of UK Wastes, Final Report for Defra, December 2006; WRAP (2006) Environmental Benefits of Recycling: An International Review of Life-cycle Comparisons for Key Materials in the UK Recycling Sector, May 2006

Our model produces similar results with regards to the GHG emissions associated with the recycling of materials and for treatment of source separated organics. However data from the Impact Assessment suggests the GHG impacts associated with landfill and incineration are much lower than the results produced by our model.

ERM's analysis bases its model of the behaviour of landfill on outputs from the GasSim model produced by the Environment Agency. We believe that the latter model considers only the cellulose element of the biodegradable carbon content, and thus grossly underestimates the biodegradable carbon content of food waste, which also contains fats and proteins.[32] In addition, the GasSim analysis assumes a significant proportion of the 'non-fossil' carbon contained within waste materials remains un-degraded even after 150 years of anaerobic activity within the landfill.[33] By contrast, our model assumes that most of the non-fossil carbon in the waste material entering the landfill will eventually degrade within this time period.

Furthermore, results from our model suggest emissions of around -300 kg of CO_2 equivalent from the incineration of one tonne of paper (excluding the non-fossil emissions) if an electrical generation efficiency of 28% was assumed. The Defra / DECC guidelines suggest emissions of -500 kg CO_2 equivalent.

It is not clear from Defra's Waste Strategy which results have been taken forward from ERM's analysis into this document Annex. ERM assume three levels of energy recovery, with two of these levels relating to electricity-only impacts:

- A 'low' recovery rate, with a generation efficiency of 20%; and
- A 'medium' recovery rate, with a generation efficiency of 40%.

Given that ERM make similar assumptions with regard to the calorific value and carbon content for paper, it seems likely that the 40% figure has been taken forward in the analysis for the Waste Strategy with regard to the generation efficiency of an electricity only incinerator. As discussed in more detail in Appendix 7 to this study, this is far in excess of that achieved by the best performing incinerators currently operating in Europe.

6.3 'Monetisation' of Greenhouse Gas Emissions

Eunomia's waste economics model has been designed to include the relevant carbon-related parameters required to include monetisation of CO_2 emissions. As mentioned above, this model was originally developed by Eunomia on behalf of the UK's Committee on Climate Change (CCC) to enable modelling of marginal abatement cost curves (MACCs) to support the analysis of the potential to meet the targets within the

[32] GasSim is based on CH4 projections produced by Golder Associates (2005) UK Landfill Methane Emissions: Evaluation of Waste Policies and Projections to 2050, Report for Defra

[33] 'Non-fossil' (or 'biogenic') carbon refers to carbon from non-fossil sources such as food and garden waste, with fossil carbon being from plastics within MSW

UK Climate Change Bill.[34] The model has subsequently been further refined via projects on behalf of Defra, Welsh Assembly Government, Scottish Government and (funded by WRAP).[35]

Reductions or increases in GHG emissions are ascribed a monetary value using the latest guidance from DECC on GHG valuation in policy appraisal.[36] Under this new approach, the precise valuation methodology differs according to the specific policy question being addressed:

- For appraising policies that reduce/increase emissions in sectors covered by the EU Emissions Trading System (ETS), and in the future other trading schemes, a 'traded price of carbon' will be used. This will be based on estimates of the future price of EU Allowances (EUAs) and, in the longer term, estimates of future global carbon market prices;
- For appraising policies that reduce/increase emissions in sectors not covered by the EU ETS (the' non-Traded Sector'), the 'non-traded price of carbon' will be used, based on estimates of the marginal abatement cost (MAC) required to meet a specific emission reduction target; and
- In the longer term (2030 onwards) consistent with the development of a more comprehensive global carbon market, the traded and non-traded prices of carbon converge into a single traded price of carbon.

Full details are provided in Appendix 10.

[34] Eunomia (2008) Development of Marginal Abatement Cost Curves for the Waste Sector, Report on behalf of the Committee on Climate Change, December 2008

[35] Eunomia (2010) Landfill Bans: Feasibility Research, Eunomia on behalf of WRAP, March 2010

[36] DECC (2009) Carbon Valuation in UK Policy Appraisal: A Revised Approach. Climate Change Economics, Department of Energy and Climate Change, July 2009

7.0 Summary of Economic Assumptions

The majority of the economic assumptions summarised in this report are based upon those developed by Eunomia in partnership with the UK Committee on Climate Change for a study to support the UK Climate Change Bill.[37] These assumptions were subsequently refined further for a study on behalf of Defra, Scottish Government, WAG and DOENI (funded by WRAP), which models the potential impact of landfill bans in the UK.[38]

In Sections 7.6 and 7.7, to describe the costs of waste treatment processes used in the modelling, we refer to both gate fees and to CAPEX and OPEX assumptions. The choice to present one or the other (or both in some cases) relates primarily to the quality of the data sources available to Eunomia at the time of writing. Particularly for novel treatment processes, for which there is little experience in the UK (and not least in London), there are significant uncertainties associated with estimates of gate fees in the current market. It is therefore usually more accurate to present CAPEX and OPEX data gained from technology suppliers, to which we have applied a weighted average cost of capital (WACC) and associated profit margin (see Section 7.1). Whilst it would have been useful to be able to present more comparable sets of financial data, we believe the approach taken represents the most sensible option for a non-site specific study of this nature.

7.1 Key Financial Incentives and Regulatory Parameters

We have carried out modelling using the 'private cost' metric, reflecting the costs, including taxes and subsidies, faced by operators in the waste market. Landfill tax charges, and support mechanisms such as the Renewables Obligation are included. The private metric applies a private Weighted Average Cost of Capital (WACC) valuing the opportunity cost of capital investments – either the cost of capital charges, or the opportunity cost of not reinvesting capital in an alternative project.

The costs will be presented in real 2009 sterling. Where estimates are based on figures from earlier years, these will be inflated by the relevant GDP deflator.

7.1.1 Weighted Average Cost of Capital

The weighted average cost of capital (WACC) is the rate of return, or cost of borrowing, that investors might seek in return for their financing of specific facilities. The WACC will vary according to the perceived risk of the associated process or technology which is being funded. The WACC is usually expressed as a percentage cost of capital.

For this study, we have taken the following approach:

---

[37] Eunomia (2008) *Development of Marginal Abatement Cost Curves for the UK Waste Sector*, Final Report for Committee on Climate Change and Defra

[38] Eunomia (2010) *Feasibility of Landfill Bans Research*, Final Report for WRAP, March 2010

- We have used a figure of 15% for large capital items of infrastructure such as incinerators, for MBT plant, and for the less well established technologies, for example, MHT (autoclave) and gasification;
- We have used a figure of 12% for items of infrastructure where the quantum of capital required is lower (IVC and AD plants). This reflects the fact that treatment facilities are likely to be constructed outside of contracts and on a more commercial basis; and
- We have used a lower figure of 10% for collection and sorting systems, as well as for landfill and open air windrow composting facilities.

This reflects, we believe, a reasonable assessment of the opportunity cost of capital going forward. It seems reasonable to suggest, however, that there might be variations in the cost of capital across technology types, and between contract (and risk-sharing) structures. For example, local authorities might well be more inclined to have recourse to Prudential Borrowing where the quantum of capital associated with a given treatment project is relatively small.

It is worth stating that the current environment is one in which the availability of credit is constrained, leading to a worsening in the terms upon which credit is made available. This would be expected to increase the cost of capital. However, the analysis here is forward looking, and extends beyond the short-term so we consider the above figures to be reasonable looking forward.

7.1.2 Revenue from Electricity Sales

The wholesale price for electricity is the central value contained within the most recent updated energy projection (UEP) published by DECC.[39] The figure used in this study is £72/MWh. In our modelling, we have assumed that, under a power purchase agreement (PPA) the generator will benefit from a proportion of the wholesale price, with the default figure set at 80%.

7.1.3 Revenue from Heat Sales

In this study, for AD, gasification and incineration (technologies that would typically export heat rather than displace alternative fuel costs) a heat off-take price of £15/MWh has been assumed.[40]

The UK Government intends to introduce a Renewable Heat Incentive (RHI), with a planned implementation date of April 2011. RHI payments will be funded by a levy on suppliers of fossil fuels for heat, including gas suppliers, and suppliers of coal, heating oil and liquefied petroleum gas (LPG). The RHI will apply at all scales, covering

[39]DECC(2009) Energy and emissions projections webpage, Table E: price assumptions, available at http://www.decc.gov.uk/en/content/cms/statistics/projections/projections.aspx (accessed 3rd November 2009)

[40] DECC(2009) Energy and emissions projections webpage, Table E: price assumptions, available at http://www.decc.gov.uk/en/content/cms/statistics/projections/projections.aspx (accessed 3rd November 2009)

a wide range of technologies including biogas produced from anaerobic digestion (for localised heat use) and injection of biomethane into the gas grid.

However, at the time of writing, no details of the likely level of support have been made available. Therefore, support from this incentive is not included in the modelling of costs for this study, although our model does allow for the addition of this at some stage in future.

7.1.4 Revenues from Sales of Biomethane for Transport Use

Using the lower end of the quoted price range, we model on the basis of revenues of £0.65/kg, which equates to £0.46 per cubic metre, based on the density of CH_4 of 0.71kg/Nm^3.

7.1.5 ROC Values and Forthcoming Feed-In Tariff

As with electricity revenues, we have assumed that 80% of the ROC value is realised by the generator in the default situation. ROCs only apply to Landfill Gas (0.25 ROCs/MWh), Good Quality CHP (1 ROC/MWh for the biomass fraction), dedicated biomass (1.5 ROCs/MWh for the biomass fraction, assuming a minimum of 90% biomass by calorific value) and AD (2 ROCs/MWh). The ROC price modelled in this study is £51/MWh.

From April 2010, there will be a Feed-In Tariff (FIT) available for smaller (<5MW) generators of renewable electricity although landfill gas will not be eligible.[41] Installations of capacity 50kW and below will only be eligible for FITs, while operators of facilities of between 50kW – 5MW will be able to make a one-off choice between the FIT and the RO.

For the purposes of the modelling we assume that AD operators opt for the FIT, receiving both the generation tariff and the export tariff, as these would be considered more 'bankable' by financiers than ROCs.

7.1.6 Levy Exemption Certificates for Good Quality CHP

Fuel used by energy from waste projects qualifying as Good Quality CHP (certified via the CHP Quality Assurance Programme (CHPQA)) is exempt from the Climate Change Levy (CCL). Electricity from new renewable energy such as anaerobic digestion is also exempt from the levy. Energy from Waste projects that do not meet the CHPQA standards are not eligible.[42]

---

[41] DECC (2009) Consultation on Renewable Electricity Financial Incentives 2009

[42] Ofgem (2009) CCL:CHP Exemption, Ofgem website, available at http://www.ofgem.gov.uk/Sustainability/Environment/CCLCHPEx/Pages/CCLCHPEx.aspx

(accessed June 2009).

Under the CCL, electricity is currently (with effect from 1 April 2009) subject to a rate of £4.70/MWh.[43] We assume, for modelling purposes, that 80% of the value is realised by the generator

7.1.7 RTFC Values and Road Duty Derogations

Suppliers of biomethane from anaerobic digestion of MSW are eligible to receive Renewable Transport Fuel Certificates under the Renewable Transport Fuel Obligation (RTFO). One certificate is issued per kg of biomethane supplied. However, as targets are currently being exceeded, we do not ascribe a value to RTFCs in our modelling. A fuel duty derogation is also available for road fuel natural gas, but as this is effectively a consumption subsidy, we assume it to be implicit in the price paid for biomethane.

7.1.8 Landfill Tax - Standard Rate

The standard rate of Landfill Tax is currently at a level of £40 per tonne, and will increase at the rate of £8 per tonne per year until it reaches £72 per tonne in 2013.[44] What levels it may be set at beyond this date are not entirely clear.[45]

For the purpose of this analysis, we assume that the tax increases to £72 per tonne, in nominal terms, in April 2013. In real terms, the value will be lower than this because of the effects of inflation. In the 2009 Budget Report, there was no announcement of intent to increase rates beyond this point, but we have taken the view for this study that the tax rate remains constant in real terms (i.e. that its nominal rate increases in line with inflation once the £72 per tonne level is reached).[44] We therefore adjust the nominal rates of landfill tax to real 2009 prices by the Bank of England's long term inflation target (2.5%) as a deflator.

7.1.9 Landfill Tax – Lower Rate

The lower rate of Landfill Tax stood at £2.00 per tonne for many years before it was increased, in 2008, to £2.50 per tonne. The 2009 Budget Report[44] stated that this lower rate applying to inert wastes will be frozen at £2.50 per tonne for 2010-11. Therefore, the lower rate tax is assumed to remain constant in nominal terms (from 2009) over time.

It is acknowledged here that the current status of incinerator bottom ash (IBA) as 'inert' for the purposes of the Landfill Tax is currently under review, as discussed in Section 7.7.11.

---

[43] HMRC (2008) Budget 2008, Climate Change Levy: Rates. Available at http://www.hmrc.gov.uk/budget2008/bn84.pdf (accessed 3rd November 2009)

[44] HM Treasury (2009) Budget 2009: Building Britain's Future, Economic and Fiscal Strategy Report and Financial Statement and Budget Report, April 2009.

[45] This information was correct at the time of submission of the final version of this report. This footnote has been added to acknowledge that the 2010 Budget clarified that the Landfill Tax will rise an extra £8 to £80 per tonne in 2014. This further increase has not been included in the modelling undertaken for this study

7.2 Collection Costs and Revenues

When recyclable materials are collected as 'source separated' from households and bring banks, the costs associated with recycling the material include a) collection costs and b) the revenue generated from the sale of that material (as set out in Appendix 6). When such materials are collected in 'co-mingled' form, the costs include a) collection costs and b) sorting costs. The costs of sorting are directly related to the gate fee (or equivalent) that London Boroughs will pay to the operator of the materials recycling facility (MRF) where the sorting takes place (see Section 7.6).

7.2.1 Scheduled Household Collections

7.2.1.1 Doorstep Properties

We have defined these households with as those with their own container for recycling (e.g. bin, box, bag), that the householder places out on near to their doorstep for collection. The cost assumptions used originate from a WRAP report on kerbside collection costs.[46]

7.2.1.2 Communal Properties

Communal properties are defined as households of multiple occupation (HMO), tower blocks, mansion blocks, and estates, which receive a communal based waste collection service, rather than a 'doorstep' one. These households comprise 32% of the households in the GLA.

Previous work carried out by Eunomia for the London Borough of Hackney has examined recycling of communal properties. We have used information acquired during this study to inform assumptions regarding the performance and cost of collecting recyclables from communal properties. The full details of this analysis are available in the Appendix 6.

7.2.2 Commercial Wastes

Within each subsector of commercial waste the size of each business varies significantly. As a result we have not modelled the differences between sub-sectors (offices, hospitality and retail) separately. Costs for the collection of commercial waste have been derived from internal data and, where possible, supplemented by data from the aforementioned study undertaken by Hyder Consulting. The internal data used is based on that used by Eunomia in previous studies on behalf of the Committee on Climate Change and Defra / WRAP.[47] [48]

---

[46] WRAP (2008) *Kerbside Recycling: Indicative Costs and Performance. Technical Annex,* Available at: http://www.wrap.org.uk/downloads/KerbsideReportAnnexFinal_1.bac022de.5634.pdf

[47] Eunomia (2008) Development of Marginal Abatement Cost Curves for the Waste Sector. Report for Committee on Climate Change, December 2008

7.3 Reuse

For the costs of collection for reuse, we have taken information from a number of industry sources.[49] An average cost of collection of £400/tonne, for the most common materials and products reused, such as wood, furniture, white goods and rubble, is used in our model. We acknowledge that this might be considered to be a higher figure than quoted for some individual projects, but we believe it represents a reasonable mean value based on the data made available for this study.

7.3.1 Modelling of Social Benefits associated with Reuse

Many recycling and re-use activities are undertaken by the third sector, where profits are re-invested to help achieve the charitable aims of the organisation. This is particularly the case for niche services such as the re-use of white goods and furniture. Collected from donors, these used goods are refurbished as required, and then donated or sold at low cost to those who would normally be unable to acquire them through usual market outlets.[50] Numerous benefits may arise from such schemes, including;

- Mutually beneficial exchange between donors wishing to dispose of an item and recipients who otherwise would not be able to obtain them; and
- Provision of work, or work experience/training, to those excluded from the mainstream job market;
- Existence value - this is the value of the reuse scheme to participants (or, indeed, the 'non-use value' to non-participants) who derive utility simply from the fact of their participation in the scheme, perhaps in relation to its socially or environmentally benign ends.[51] Donors of gifted furniture often derive additional utility from donating to a 'good cause' as opposed to the usual routes of disposal (the so-called 'warm glow' effect); and
- Relief of client hardship on the part of those who receive the reused goods, a key social aim of many reuse organisations, is also identified as a key benefit, and one that is typically not included within CBA.

Placing a value on these benefits, however, is problematic in that they are often implicit, hard to quantify, or occur at 'downstream' points, distant from the tangible activities of the organisation. Moreover, these benefits are not readily amenable to inclusion within a cost-benefit analysis as presented for this study.

---

[48] Eunomia (2010) The Environmental, Economic and Practical Impacts of Landfill Bans: Feasibility Research. Report for WRAP, March 2010

[49] These include LCRN and Caroline Lee-Smith, formerly of FRN, now an independent consultant

[50] Alexander, C. and Smaje, C. (2008) Evaluating third sector reuse organisations in the UK: Case-studies and analysis of furniture reuse schemes. Resources Conservation & Recycling 52 (2008), 719-730

[51] Hanley, N. and Slark, R. (1994) Cost-Benefit Analysis of Paper Recycling: A Case Study and Some General Principles. J Environmental Planning & Management 1994;37:189-97.

7.3.1.1 Employment

Alexander and Smaje (2008) note that many reuse schemes take on volunteers or employees with the explicit objective of improving the welfare of those taken on. Often these people have particular needs which mean they are disadvantaged in the mainstream job market, such as mental health problems or learning difficulties.

In CBA, job creation is not counted as a benefit, as it is taken to represent a transfer of resources from one sector to another.[52] More usually, labour is in fact represented as a cost. However, Alexander and Smaje (2008) argue that in the case of social enterprise, there is a net social benefit involved, as schemes take on people who would not otherwise find employment. Furthermore, in so doing, they could serve to mitigate negative social outcomes which might otherwise require a greater input of public resources. Figures are presented in this study to show the net benefit to society of taking individuals out of social security and into salaried payment. However, a number of uncertainties remain in the application of such figures to reuse schemes.

7.3.1.2 Approach used in this Study

While we note the monetised benefits from the Alexander and Smaje study, we feel, as do the authors, that further research needs to be undertaken to obtain more reliable figures that could readily be transferred to a study such as this one. We recognise that CBA does not capture the widest possible range of value in relation to reuse schemes, but in the absence of further evidence, we are unwilling to include any such figures in our analysis.

7.4 On-The-Go Recycling

We have assumed in the modelling that the operational cost of on-the-go recycling bins will be zero, as it is assumed collection costs are covered by the value of materials recovered. This is achievable because we assume that low quantities of material can be collected on existing municipal rounds, and thus the marginal cost of collection is very low. A capital cost of £500 per bin has been assumed. This figure represents an average of costs given to Eunomia by London Boroughs currently operating on-the-go recycling collections (see the Appendix 6 for more details).

7.5 Reuse and Recycling Centres

The approach taken to modelling the change in cost of reaching the required level of recycling performance of Reuse and Recycling Centres (RRCs) has been to model an average for each of the 37 RRC sites. This approach reflects the likelihood that performance (and the steps already planned or taken to improve performance) vary considerably between individual sites. Modelling each site individually suggests a level of detail not achievable in a study of this nature.

[52] Ackerman F, Porter R, Pearce D, Dijkgraaf E, Volebergh H. Rethinking the Waste Hierarchy. Copenhagen, Denmark: Environmental Assessment Unit, 2005.

In reality, different sites will target different materials and performance improvement initiatives in different orders in future years. As all of the material that needs to be recycled in each scenario will have to be captured at some point, we have made the somewhat crude (but necessary) methodological decision to calculate an overall average cost per tonne of additional recycling at RRC sites for all materials. This is a less problematic methodology for RRC sites than for household collected waste because a larger part of the cost of dealing with any tonne of waste is fixed (i.e. provision of infrastructure, staff etc.) rather than variable (i.e. the cost or revenue associated with a particular material).

We have not modelled marginal costs per tonne of improvement, but average costs per tonne. A bespoke model was developed to calculate the average per tonne cost using assumptions derived from the National Assessment of Civic Amenity Sites (NACAS) study, which sought, primarily by means of multiple regression analysis of date from hundreds of CA sites across the UK, to understand the factors that lead to increased recycling and re-use performance at CA sites.[53] These measures have been supported by a 2008 report examining best practice for RRCs in the GLA.[54]

7.6 Materials Recycling Facilities

Materials recycling facilities (MRF) costs are modelled using the approach outlined in the WRAP MRF Costing Model User Guide.[55] We have calculated an associated gate fee and have set this within a range of £27 and £34 per tonne, which includes onward sales of materials by the MRF operator. Due to the close relationship between material sales and other financial parameters, detailed CAPEX and OPEX data for MRFs cannot be easily extracted for presentation in this study. Further detail is available in Appendix 7.

7.7 Waste Treatment Processes

As mentioned above, the costs presented in this Section were developed in the process of a number of studies on behalf of Defra and the CCC. Only headline figures are presented. Full descriptions and references are to be found in Appendices 7.

As discussed above, to describe the costs of waste treatment processes used in the modelling, we refer to both gate fees and to CAPEX and OPEX assumptions. The choice to present one or the other (or both in some cases) relates primarily to the quality of the data sources available to Eunomia at the time of writing. Particularly for novel treatment processes, for which there is little experience in the UK (and not least in London), there are significant uncertainties associated with estimates of gate fees in the current market. It is therefore usually more accurate to present CAPEX and OPEX data gained from technology suppliers, to which we have applied a weighted

---

[53] Future West and Network Recycling (2004) *National Assessment of Civic Amenity Sites*, Final Report for Biffaward, March 2004

[54] Resource Futures (2008) London Reuse and Recycling Best Practice Guidance, RF Project no.: 376

[55] WRAP (2006) MRF Costing Model User Guide, September 2006

average cost of capital (WACC) and associated profit margin (see Section 7.1). Whilst it would have been useful to be able to present more comparable sets of financial data, we believe the approach taken represents the most sensible option for a non-site specific study of this nature.

It should be noted that the operating costs (OPEX) presented in Sections 7.7.1 to 7.7.16 are exclusive of any ROC revenues. It should be acknowledged, however, that these additional revenues are included in the overall results presented in Section 8.0, and are calculated from both the quantity of energy generated per tonne of waste treated and the price of ROCs (see Appendix 7 and Section 7.1.5 for further information).

7.7.1 Open Air Windrow Composting

We have modelled on the basis of a facility of the order 20,000 tonnes and have taken figures from previous studies undertaken by Eunomia, and inflated these to give a unit capital cost, including land, of £85 per tonne of throughput.[56]

Operating costs have been estimated at £5 per tonne before the costs of disposal of rejects. Annual maintenance costs are modelled as 3% of unit capital cost per tonne, which equates to £2.55 per tonne throughput. We have assumed 5% of input material is rejected and sent to landfill, which attracts Landfill Tax at standard rate.[57] We have assumed that compost has a sale value of £1.25/tonne.

7.7.2 In-Vessel Composting (IVC)

For a 30,000 tonne plant, we assume a capital cost of £165 per tonne. For operating costs, we use a figure of £10 per tonne. Maintenance costs are not included in this operating cost figure, but are included in the annual costs, at 5% of capital cost, representing £8.25 per annum.

We assume rejects are 5% of input material and that these are sent to landfill where they attract landfill tax at the standard rate. As with open-air windrow facilities, again we have assumed that compost has a sale value of £1.25/tonne.

7.7.3 AD with Electricity Only

We have used a figure of £300/tonne for unit capital costs. For operating costs, we have used a figure of £30 per tonne. We believe this to be representative of facilities of scale 20-30,000 tonnes capacity, with appropriate post-treatment of the digested organic waste. As for compost, we assume rejects are 5% of input material, but that digestate has zero sale value.

---

[56] Eunomia (2002) *The Legislative Driven Economic Framework Promoting MSW Recycling in the UK*, Final Report to the National Resources and Waste Forum;

[57] In theory, one might suggest that this type of material could be used for other purposes. In practice, rejects from garden waste facilities tend to consist more of grit and stones, and to a lesser degree, materials associated with garden implements which find their way into the facility. The potential for, for example, energy recovery is less obvious with such reject streams.

7.7.4 AD with CHP

In this study, we have estimated capital costs for the useful deployment of CHP at an additional £1.65 million in capital terms for a 20,000 tonne per annum facility. We have also added £1 per tonne to the operating costs, however the specifics will vary with the location and local opportunities for heat use of any given plant. Therefore for modelling purposes, we assume a total capital cost of £382.50 per tonne, and an operating cost of £31/tonne. Again, we assume rejects are 5% of input material, and that digestate has zero sale value.

7.7.5 AD with Gas Upgrading for Use as Vehicle Fuel

We model a capital cost of £349 per tonne, with operating costs of £36.45 per tonne. Again, we assume rejects are 5% of input material, and that digestate has zero sale value.

7.7.6 AD with Biogas Up-grading and Injection into the Natural Gas Grid

We have assumed that the cost of upgrading for use in the grid is similar to that of upgrading for vehicle fuels. This is due to insufficient data to assume otherwise as the technology is not yet available in the UK and there is a lack of transferable information from existing facilities. It is important to recognise, however, that this is likely to be a technically difficult option for the foreseeable future, whatever its presumed merits may be. Again, we assume rejects are 5% of input material, and that digestate has zero sale value.

7.7.7 Non-hazardous Landfill

We assume a capital cost of £115 per tonne of installed capacity, and operating costs of £7 per tonne, whilst restoration, post-closure and aftercare are estimated to cost a further £7 per tonne. Based on these assumptions, the estimated gate fees modelled for the landfilling of London's waste are summarised in Table 7-1.

Table 7-1: Non-hazardous Landfill Gate Fees (including Landfill Tax)

Year	2008	2009	2010	2011	2012	2013-2031[1]
Gate Fee	£64	£72	£79	£87	£93	£100

Note:

1. This information was correct at the time of submission of the final version of this report. This note has been added to acknowledge that the 2010 Budget clarified that the Landfill Tax will rise an extra £8 to £80 per tonne in 2014. This further increase has not been included in the modelling undertaken for this study

7.7.8 Hazardous Landfill

Some facilities generate a residue which is classified as hazardous, for example fly ash from incineration. For the purpose of this study, we have not included a model, as such, of a hazardous waste landfill site. We have assumed, however, a cost per tonne of landfilling hazardous waste of £180 before landfill tax, but including transport costs.

7.7.9 Incineration with Electricity Only

We model capital costs at £500 per tonne of installed capacity. For operating costs, before revenues from electricity generation and costs of managing residues, we have used a figure of £20 per tonne. As noted above, operating costs also do not include fuel costs. The gate fee we have estimated for new build plant is £98 per tonne of waste treated. For existing plants we assume a gate fee of £74 per tonne of waste treated.

7.7.10 Incineration with CHP

In addition to incineration with electricity only, we model on the basis of additional CAPEX of £107.50 per tonne of installed capacity, and additional OPEX of £1.18 per tonne. This gives a total CAPEX of £607.50 per tonne, and a total OPEX of £21.18 per tonne.

7.7.11 Bottom and Fly Ash from Incineration

For bottom ash, we assume that on average, around two-thirds of material is put to some form of use in the construction industry. The remaining third is assumed to be landfilled as 'inert', and thus attracts the lower rate landfill tax of £2.50/tonne. It should be noted, however, that there is currently a HM Treasury consultation process taking place to consider whether bottom ash should attract the standard rate of Landfill Tax, and thus in future years its associated costs may be significantly higher.[58]

Fly ash is assumed to be landfilled at a hazardous waste landfill. As stated in Section 7.7.8, we have not modelled these costs explicitly, but have used a fixed pre-tax figure for the costs of landfilling, inclusive of haulage.

7.7.12 MBT Aerobic Biodrying Facility Preparing SRF

In principle, the costs of this type of system will be different depending upon whether the SRF which is being prepared is to be of higher or lower quality. We have used figures for CAPEX of £200 per tonne, with OPEX of £17 per tonne before residue disposal. It should be noted that the reality is that both the capital costs and the costs of dealing with residues will depend upon the detailed configuration of the system and the specification to which SRF is being produced.

7.7.13 Gasifier with a Steam Turbine

We have used a figure for capital costs of £550 per tonne where a steam turbine is used. For operating costs we use a figure of £25 per tonne. As noted above, operating costs do not include ROC revenues or fuel costs.

---

[58] HM Treasury, HMRC (2009) Modernising Landfill Tax Legislation, April 2009. Available at http://www.hm-treasury.gov.uk/d/Budget2009/bud09_landfill_tax_964.pdf (accessed September 2009).

7.7.14 Gasifier with a Gas Engine

We model capital costs of £600 per tonne where a gas engine is used, with operating costs of £25/tonne. Again, as noted above, operating costs do not include ROC revenues or fuel costs.

7.7.15 Slag from Gasification

We assume slag from gasification is treated in the same way as incinerator bottom ash, as discussed in Section 7.7.11. Therefore, we assume that around two-thirds of material is put to some form of use in the construction industry, at a cost of £5/tonne. The remaining third is assumed to be landfilled at non-hazardous waste sites, and attracts the lower rate of Landfill Tax.

7.7.16 Autoclaving

We model on the basis of £270/tonne capital costs, and £13/tonne operating costs.

8.0 Results from Scenario Modelling

The results presented in this Section reflect the outputs from the quantitative modelling work undertaken for this study. It is acknowledged, however, that there are many other more subtle factors that will affect the nature of waste management in London than those included in our model. Behavioural change, for example, whilst potentially being one of the most important factors in achieving high levels of recycling is very difficult to quantify and monetise within modelling of this nature. Such issues have therefore not been included within our core analysis, but are explored further in Section 10.0.

To understand the costs, and environmental benefits, of the scenarios modelled in this study, it is necessary to first appreciate the switches of waste that occur within each, as detailed in Section 5.0. The key outputs from the study described in this Section, therefore, are:

- Total Costs of Waste Management;
- GHG emissions from Waste Management;
- Monetised Carbon Impacts from Waste Management;
- Waste Sent to Landfill; and
- Heat and Power Generated.

These outputs are presented in Sections 8.1 to8.5.

8.1 Total Costs and Savings of Waste Management Scenarios

As mentioned above, the changes in collections systems and resulting waste flows from the multiple different collection scenarios are described in Section 5.0. These changes affect the relative costs of the scenarios with <u>different</u> collection systems in place. The remaining difference in costs, between the scenarios (with the same collection systems in place), relates directly to the varying costs of residual waste management. Therefore, the two key components of the additional cost to London in meeting the targets set out in the draft strategy are a) collection costs and b) treatment infrastructure costs.

To explain the total costs of waste management, for all the scenarios, it is important to first look at the breakdown of costs for the 2031 'Do Nothing New' baseline compared with four alternative scenarios. As shown in Figure 8-1, we have provided assessment of four scenarios which have a different focus of collection (see Section 4.3 for further details), but the same residual treatment infrastructure.

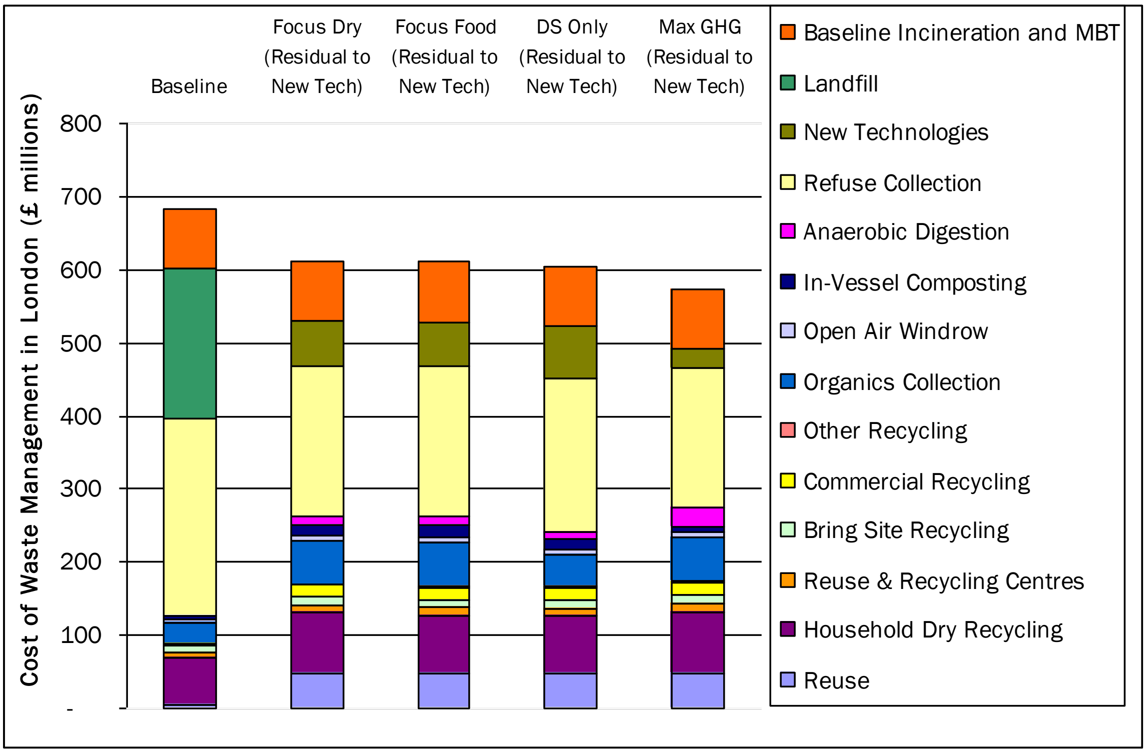
The key differences in the change in waste management costs for these four scenarios compared to the 'Do Nothing New' baseline, are:

- Reduction in cost of landfilling;
- Increase in cost for alternative (non-landfill) residual treatment;
- Decrease in the collection costs of refuse, through both a) less tonnage and b) a switch to fortnightly collections;

- Increase in household *collection* costs for dry recyclables and organics;
- Increase in costs of reuse, and other recycling / composting (albeit as part of this metric, there is an increase in revenues from sales of recyclable materials); and
- Increase in *treatment* costs for organic wastes.

Figure 8-1 also shows that when there is a ‘focus on food’ the associated collection and treatment costs are marginally higher than in the other scenarios. When the ‘Max GHG Abatement’ scenario is considered, however, the quantity of residual waste decreases significantly, such that the costs of residual waste collection and treatment, also falls significantly, suggesting this is the most cost effective option. It should also be noted that although the ‘Doorstep Only’ scenario appears to result in lower costs than the ‘focus on dry’ scenario, not enough material can be recovered to meet the 60% target in 2031. ‘Other recycling’ refers to tonnes from street recycling bins and non-contracted voluntary kerbside tonnes. Pre-treatment is included in the cost of incineration. New technologies refer to the combination of pre-treatment and thermal treatment used in a scenario.

Figure 8-1: Potential (Annual) Costs of Waste Management in London in 2031



8.1.1 Additional Costs of Waste Management Scenarios

Waste treatment infrastructure costs are calculated from the tonnage waste flows detailed in Section 5.0 and the annualised costs summarised in Section 7.7. Annualised costs are derived from the annual costs of capital expenditure, operational costs, disposal costs and revenues from energy generation and / or compost sales. For each scenario, these costs are provided in Table 8-1 and Table 8-2, with regard to additional CAPEX/OPEX and annualized costs respectively.

The figures for CAPEX in each table represent the cumulative costs of building infrastructure, not the CAPEX required in that year. It should also be noted that the CAPEX is not all being incurred in any given year, as the costs are annualised and discounted. In cases where the total CAPEX falls from one year to the next, this indicates that if all the infrastructure was built in the first year there would be over capacity in later years, due to greater amounts of waste being diverted to recycling. The OPEX figures represent the total operating costs of the new infrastructure in that year only.

The total annualised costs presented in Table 8-2 represent the annualised cost per tonne (equivalent to the estimated gate fee) multiplied by the tonnage treated in each year.

It should be noted that the information in Table 8-1 and Table 8-2 is a reflection of expenditure only and does not include the savings delivered by the scenarios, the detail of which is provided in Section 8.1.2.

Table 8-1: Additional Cumulative CAPEX and Annual OPEX of Waste Management Scenarios (relative to ‘Do Nothing New’ Baseline)

Recycling Approach	Residual Approach	Scenario	CAPEX (£M)			OPEX (£M)		
			2015	2020	2031	2015	2020	2031
‘Do Nothing New’ Baseline		1	£0	£0	£0	£0	£0	£0
‘Do Nothing New’	New Tech (unrefined)	2	£466	£550	£882	£53	£62	£97
	New Tech (high-biomass)	3	£565	£665	£1,062	£54	£63	£99
‘Focus on Dry’	‘Do Nothing New’	4	£83	£104	£140	£16	£20	£27
	New Tech (unrefined)	5	£199	£190	£370	£29	£30	£52
	New Tech (high-biomass)	6	£230	£215	£424	£30	£30	£53
‘Focus on Food’	‘Do Nothing New’	7	£83	£104	£140	£16	£20	£27
	New Tech (unrefined)	8	£199	£190	£370	£29	£30	£52
	New Tech (high-biomass)	9	£234	£217	£427	£31	£31	£53
‘Doorstep Only’	New Tech (high-biomass)	10	£235	£236	£461	£30	£32	£56
‘Max GHG Abatement’	New Tech (high-biomass)	11	£239	£164	£327	£33	£33	£52

Table 8-2: Annualised Additional Costs of Waste Management Scenarios (relative to ‘Do Nothing New’ Baseline)

Recycling Approach	Residual Approach	Scenario	Annualised Costs		
			2015 (£M)	2020 (£M)	2031 (£M)
‘Do Nothing New’ Baseline		1	0	0	0
‘Do Nothing New’	New Tech (unrefined)	2	121	135	213
	New Tech (high-biomass)	3	125	141	227
‘Focus on Dry’	‘Do Nothing New’	4	21	26	36
	New Tech (unrefined)	5	51	48	91
	New Tech (high-biomass)	6	54	50	96
‘Focus on Food’	‘Do Nothing New’	7	21	26	36
	New Tech (unrefined)	8	51	48	91
	New Tech (high-biomass)	9	55	51	97
‘Doorstep Only’	New Tech (high-biomass)	10	55	54	104
‘Max GHG Abatement’	New Tech (high-biomass)	11	57	44	81

8.1.2 Total Savings Delivered by Scenarios

Table 8-3 below shows the financial savings (represented by negative figures) achieved under different scenarios in given years. The savings presented are relative to the 'Do Nothing New' baseline for each year. The key findings from these results can be summarized as follows:

- When the level of recycling does not increase, there are no overall financial savings. This is shown by the additional costs generated under Scenarios 2 and 3 where baseline recycling increases only marginally (due to recovery of materials during residual treatment) above today's levels;
- Focusing on collection of dry materials for recycling appears to provide greater financial savings than when the focus is on collecting food waste in London. This is largely due to the fact that the net cost of collection, and treatment of food waste is higher than for dry materials on a per tonne basis;
- When higher recycling targets are modeled, greater financial savings may be achieved through the additional savings in collection of refuse and disposal of residual waste. It should be noted, however, that the uncertainties in the costs associated with modelling higher levels of recycling are not conveyed adequately by single point estimates. Therefore, we use 'Monte Carlo' analysis to draw out these uncertainties, and provide a range to the total costs as presented in Section 9.0;
- The overall savings delivered by Scenarios 4 to 11 result from the greater relative reduction in cost of new recycling and composting services in comparison to sending the same material for residual treatment, or sending it to landfill as part of the residual waste stream under the 'Do Nothing New' Scenarios 1 to 3. When residual waste is diverted from landfill to residual treatment, the costs of waste management increase, notwithstanding the increase in Landfill Tax. This is due to our assumptions relating to the higher average gate fees compared with landfill, for some configurations of residual treatment which are not currently commercially demonstrated, and the roll out of this infrastructure (see Section 3.4.6.2). In the future, investor confidence in residual treatment technologies will increase as they come to market, potentially lowering capital expenditure, and the resultant gate fee. Furthermore, if the Landfill Tax continues to rise at current rates, the 'tipping point' for the more expensive residual treatments modeled in this study will be reached (i.e. they become cheaper than landfill), providing further financial savings for London Boroughs. This, of course, all becomes trivial if Defra press ahead with a number of landfill bans, as the effective cost of landfilling, from an economic perspective, will become infinite;[59] and

---

[59] Defra (2010) *Options to further restrict waste to landfill – Consultation Stage Impact Assessment*, Accessed 30th April 2010, http://www.defra.gov.uk/corporate/consult/landfill-restrictions/20100318-landfill-restrictions-condoc-ia.pdf

- The total savings delivered by Scenario 10 ('doorstep only') are greater than all other scenarios aside from under the 'max GHG abatement' scenario. This is because under the assumptions used in our model, residual waste treatment is cheaper (on a tonne for tonne basis) than collecting recyclables from 'hard to reach' properties (which are ignored under the 'doorstep only' scenario). It should be acknowledged, however, that under the 'doorstep only' scenario, the Mayor's proposed 60% recycling target in 2020 *or* 2031 <u>cannot</u> be met.

Table 8-3: Financial Savings (net of costs) relative to 'Do Nothing New' Baseline

Recycling Approach	Residual Approach	Scenario	2015 (£M)	2020 (£M)	2031 (£M)	NPV: 2008-2031 (£M)	Ranking
'Do Nothing New' Baseline		1	-	-	-	-	9
'Do Nothing New'	New Tech (unrefined)	2	10	6	8	111	10
	New Tech (high-biomass)	3	14	11	22	217	11
'Focus on Dry'	'Do Nothing New'	4	-26	-58	-78	-628	3
	New Tech (unrefined)	5	-24	-57	-76	-599	5
	New Tech (high-biomass)	6	-25	-55	-72	-578	7
'Focus on Food'	'Do Nothing New'	7	-26	-58	-78	-628	3
	New Tech (unrefined)	8	-24	-57	-76	-599	5
	New Tech (high-biomass)	9	-24	-56	-73	-573	8
'Doorstep Only'	New Tech (high-biomass)	10	-36	-62	-79	-679	2
'Max GHG Abatement'	New Tech (high-biomass)	11	-43	-78	-92	-838	1

8.2 Greenhouse Gas Emissions from Waste Management Scenarios

The financial cost savings delivered by different waste management scenarios represent a critical, but not isolated goal within the Mayor's new Draft MWMS. The climate change impacts associated with Mayoral policy are increasingly important to decision-making. Analysis the greenhouse gas savings that may occur from the different scenarios modelled in this study, therefore, gives a wider scope of credibility to this study as a basis for policy-making at the GLA. In this context, the GHG emission reductions delivered by the different scenarios, relative to the 'Do Nothing New' baseline, are presented in Table 8-4.

Table 8-4 Greenhouse Gas Savings (relative to 'Do Nothing New' Baseline)

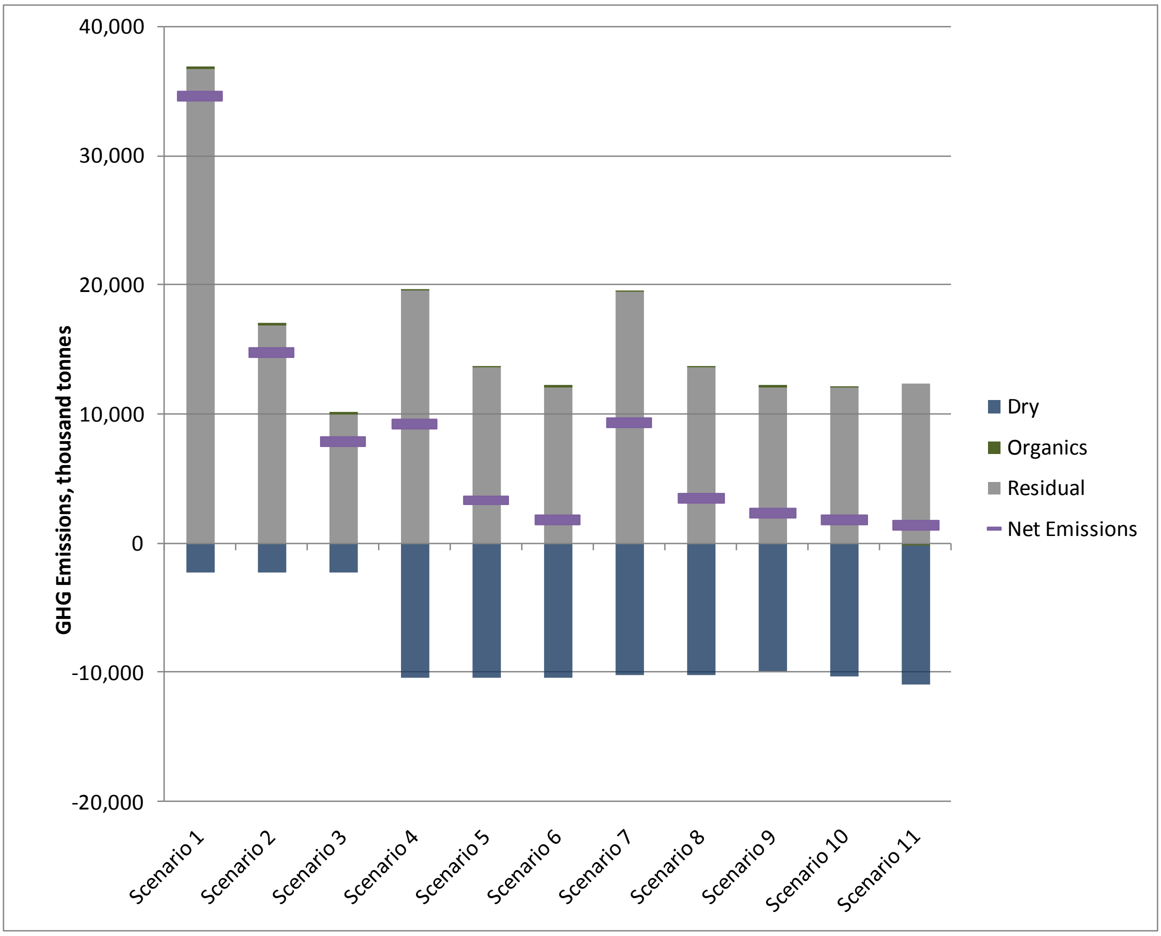
Recycling Approach	Residual Approach	Scenario	Cumulative GHG Savings 2008-2031 (Mt)	Ranking
'Do Nothing New' Baseline		1	0.0	**11**
'Do Nothing New'	New Tech (unrefined)	2	-19.9	**10**
	New Tech (high-biomass)	3	-26.8	**7**
'Focus on Dry'	'Do Nothing New'	4	-25.4	**8**
	New Tech (unrefined)	5	-31.3	**5**
	New Tech (high-biomass)	6	-32.8	**2**
'Focus on Food'	'Do Nothing New'	7	-25.4	**8**
	New Tech (unrefined)	8	-31.3	**5**
	New Tech (high-biomass)	9	-32.7	**4**
'Doorstep Only'	New Tech (high-biomass)	10	-32.8	**3**
'Max GHG Abatement'	New Tech (high-biomass)	11	-33.2	**1**

Figure 8-2 shows the total, cumulative, GHG emissions by source for waste management in London. These emissions are reported according to IPCC reporting guidelines, whereby the benefits of materials reprocessing overseas do not contribute to the GHG balance. As such, due to the current high level of overseas reprocessing of materials collected in the UK, all scenarios result in net GHG emissions. If a greater level of reprocessing was to occur in the UK, then the benefits from recycling dry materials would be counted under the under the IPCC guidelines, which may result in overall net GHG savings under some or all scenarios. This is tested by way of sensitivity analysis in Section 9.6.

The key findings from the results presented in both Table 8-4 and Figure 8-2 can be summarized as follows:

- As recycling increases, GHG savings increase significantly;
- Scenario 11 ('Max GHG abatement' with residual waste processed into a -biomass SRF for gasification) appears to provide the greatest net GHG savings. It should be noted that the economic savings are also greatest under this scenario;
- The majority of GHG savings in all scenarios can be attributed to the diversion of residual waste from landfill to residual treatment processes. Where the tonnage input of residual waste is the same (i.e. within each collection scenario) the relative impact of the different treatments is the key determinant of the total GHG savings; and
- Greater GHG benefits can be achieved when residual waste is managed through processes that produce a high biomass SRF for treatment at a dedicated combustion or gasification facility. The savings accrue because it is assumed both that reject streams have been stabilized prior to landfill, and that only low levels of fossil based carbon (i.e. plastics) are treated and thus released as CO_2 into the atmosphere. It should be noted that, in line with IPCC reporting guidelines, these results do not include non-fossil CO_2, which would increase the emissions from all scenarios.

Figure 8-2 Breakdown of Cumulative GHG Emissions (2008 to 2031)



8.3 Modelling of 'Monetised' Greenhouse Gas Emissions

Within this Section, we have provided analysis of the monetised CO_2 benefits of each scenario alongside the financial costs of waste management.[60] It should be noted, however, that in this study financial costs are modeled using a 'private' metric, which includes all Government incentives, such as ROCs. As such, monetized CO_2 impacts cannot simply be added to derive a 'net benefit to society' as would be the case when conducting full CBAs as part of Government Impact Assessments. Analysis of both figures together remains useful, however, to allow an understanding of the potential implications of the new MWMS for London's economy and whether, in financial terms, the GHG savings appear significant.

The net present value (NPV) both of the financial costs and monetized CO_2 benefits, from 2008 to 2031, are presented in Table 8-5. The figures are presented relative to the 'Do Nothing New' baseline scenario. Table 8-5 shows that the CO_2 benefits for all

[60] See Section 6.3 for discussion of the approach to monetization of CO_2

scenarios appear to be significant compared to the potential financial costs of waste management in London, further strengthening the case for the recycling targets set out in the Mayor's Draft MWMS. It should also be noted that the financial savings and environmental benefits are greatest under the 'Max GHG Abatement' scenario.

Table 8-5: Financial Costs and Monetised CO_2 Benefits relative to the 'Do Nothing New' Baseline (NPV: 2008 to 2031)

Recycling Approach	Residual Approach	Scenario	Financial Costs or Benefits (£M)	Monetised Costs of CO_2 emissions (£M)
'Do Nothing New' Baseline		1	0	£0
'Do Nothing New'	New Tech (unrefined)	2	£111	-£1,363
	New Tech (high-biomass)	3	£217	-£1,874
'Focus on Dry'	'Do Nothing New'	4	-£628	-£1,710
	New Tech (unrefined)	5	-£599	-£2,117
	New Tech (high-biomass)	6	-£578	-£2,225
'Focus on Food'	'Do Nothing New'	7	-£628	-£1,710
	New Tech (unrefined)	8	-£599	-£2,117
	New Tech (high-biomass)	9	-£573	-£2,223
'Doorstep Only'	New Tech (high-biomass)	10	-£679	-£2,216
'Max GHG Abatement'	New Tech (high-biomass)	11	-£838	-£2,270

8.4 Waste sent to Landfill

In line with the new Draft MWMS, it has been important to minimise the tonnage of waste sent to landfill within our modelling. In Table 8-6, we have therefore provided analysis of the percentage of 'untreated and 'pre-treated' waste, i.e. that which has been sorted or processed at a waste management facility, which would be sent to landfill under each scenario.

Table 8-6 shows that under all 'do something' scenarios, there is zero 'untreated' waste, and only very limited tonnages of 'treated' waste, sent to landfill in 2031.

It should also be noted that the performance of residual technologies may have improve in the period to 2031, such that both materials recovery rates increase and reject rates decrease, reducing the overall tonnage sent to landfill. This is also likely to be aided by new markets opening up for recovered materials such as mixed plastics.

Table 8-6 Proportion of Total Waste sent to Landfill (2031)

Recycling Approach	Residual Approach	Scenario	Total Untreated Waste to Landfill	Total Treated Waste to Landfill
'Do Nothing New' Baseline		1	49%	3%
'Do Nothing New'	New Tech (unrefined)	2	0%	19%
	New Tech (high-biomass)	3	0%	19%
'Focus on Dry'	'Do Nothing New'	4	13%	3%
	New Tech (unrefined)	5	0%	7%
	New Tech (high-biomass)	6	0%	8%
'Focus on Food'	' Do Nothing New'	7	13%	3%
	New Tech (unrefined)	8	0%	7%
	New Tech (high-biomass)	9	0%	8%
'Doorstep Only'	New Tech (high-biomass)	10	0%	8%
'Max GHG Abatement'	New Tech (high-biomass)	11	0%	4%

8.5 Heat and Power Generated

Table 8-7 below shows the net change in energy generation from 2008 levels. A large proportion of energy generated is from the thermal processing of residual waste. Thus, if the total quantities of residual waste fall as recycling increases, or if the level of residual waste treatment falls, the total level of energy generation also falls. In this context, it should be noted that for Scenario 1, as the Edmonton incinerator is assumed to cease to operate in 2020/21, there is a reduction in energy generated in 2031 compared with 2008.

Table 8-7: Energy Generated under each Scenario (relative to 2008)

Recycling Approach	Residual Approach	Scenario	2015 (MWh)	2020 (MWh)	2031 (MWh)
'Do Nothing New' Baseline		1	314,546	335,093	-24,055
'Do Nothing'	New Tech (unrefined)	2	381,662	524,559	724,100
	New Tech (high-biomass)	3	526,452	563,961	159,611
'Focus on Dry'	'Do Nothing'	4	215,552	211,406	-175,031
	New Tech (unrefined)	5	232,286	241,175	19,826
	New Tech (high-biomass)	6	273,205	252,557	-124,125
'Focus on Food'	' Do Nothing'	7	215,552	211,406	-175,031
	New Tech (unrefined)	8	232,286	241,175	19,826
	New Tech (high-biomass)	9	275,253	253,136	-122,922
'Doorstep Only'	New Tech (high-biomass)	10	286,189	274,475	-109,696
'Max GHG Abatement'	New Tech (high-biomass)	11	290,406	220,212	-133,570

9.0 Sensitivity Analysis

9.1 Risk Analysis of Central Cost Figures

As mentioned in Section 8.0, there are many uncertainties associated with modelling of this nature. These mainly relate to forecasts for costs and performance of waste collection and recycling, especially those relating to 'communal' properties. As the model extends forward to 2031, these uncertainties only increase further. As noted above, presentation of point estimates can also lead to a perception of accuracy which is likely to be spurious. We have therefore used a 'Monte Carlo' analysis tool (Crystal Ball®) to test the sensitivity of the total cost of waste management, to changes in key assumptions.

Using this approach, Figure 9-1 shows the 95% confidence interval for three key scenarios modelled in this study. These represent the four main variations in collection systems, with the remaining residual waste, under all three scenarios, sent to an autoclave facility to generate a high-biomass SRF for combustion or gasification.[61] The results in Figure 9-1 highlight that:

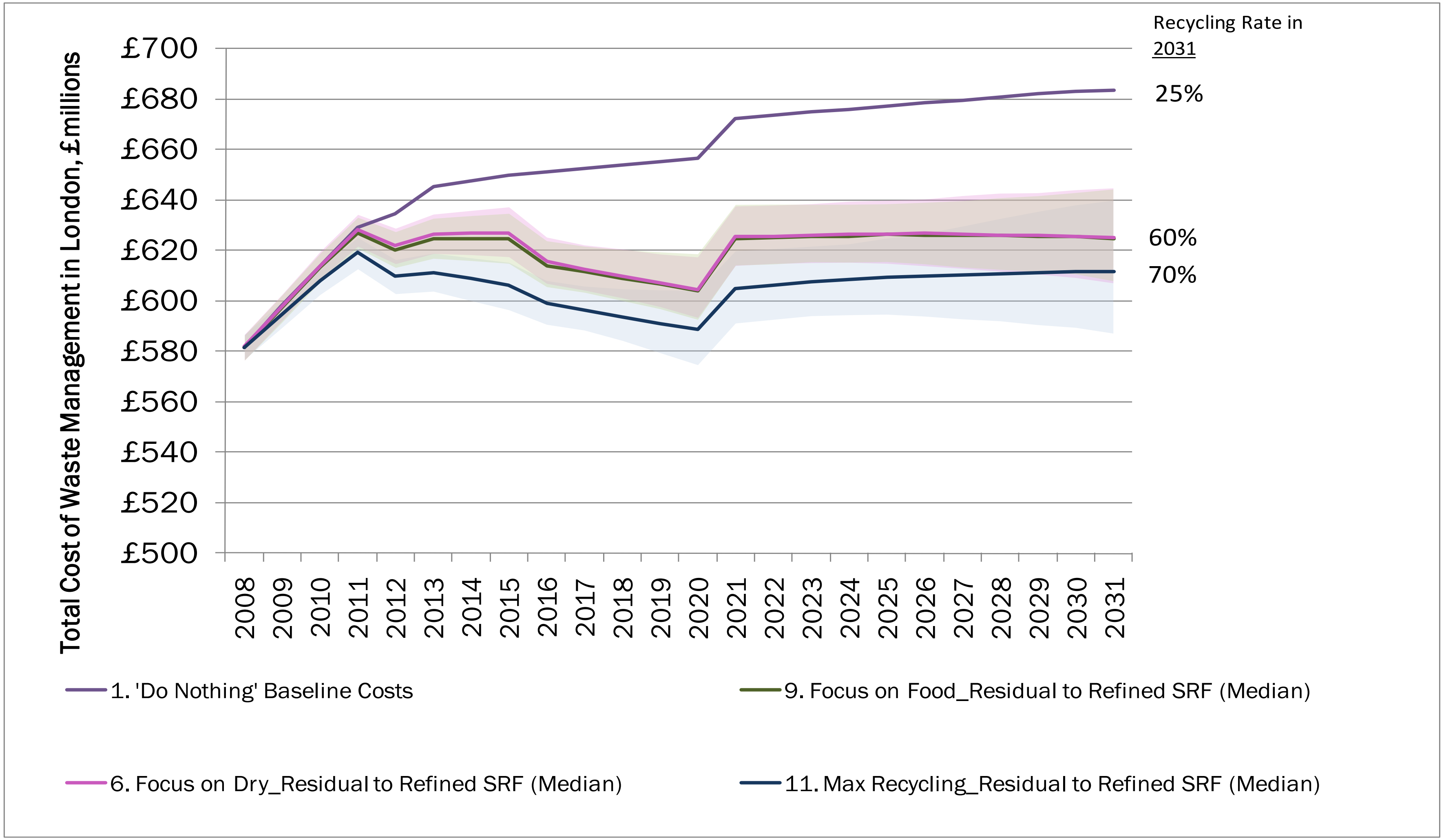
- The central results presented in Section 8.0 above provide a relatively sound basis for policy-making, but do include a large range of uncertainty;
- Under all sensitivity cases modelled, there appear to be financial savings, relative to the current baseline;
- The costs of waste management to London, in meeting the targets set out in the strategy are likely to fall within the confidence intervals presented;
- Aiming for higher recycling rates (70% by 2031) may achieve greater financial savings, but the uncertainty associated with these costs is much greater, such that the total costs could exceed those required to meet the 60% target in 2031.

It should be noted that the sharp increase in costs around 2020 is when the Edmonton incinerator is assumed to cease operation, and waste requires treatment at new-build facilities with higher associated gate fees.

---

[61] This residual scenario was chosen as it was shown to have the greatest CO_2 benefit

Figure 9-1: Analysis of Uncertainty of Total Waste Management Costs

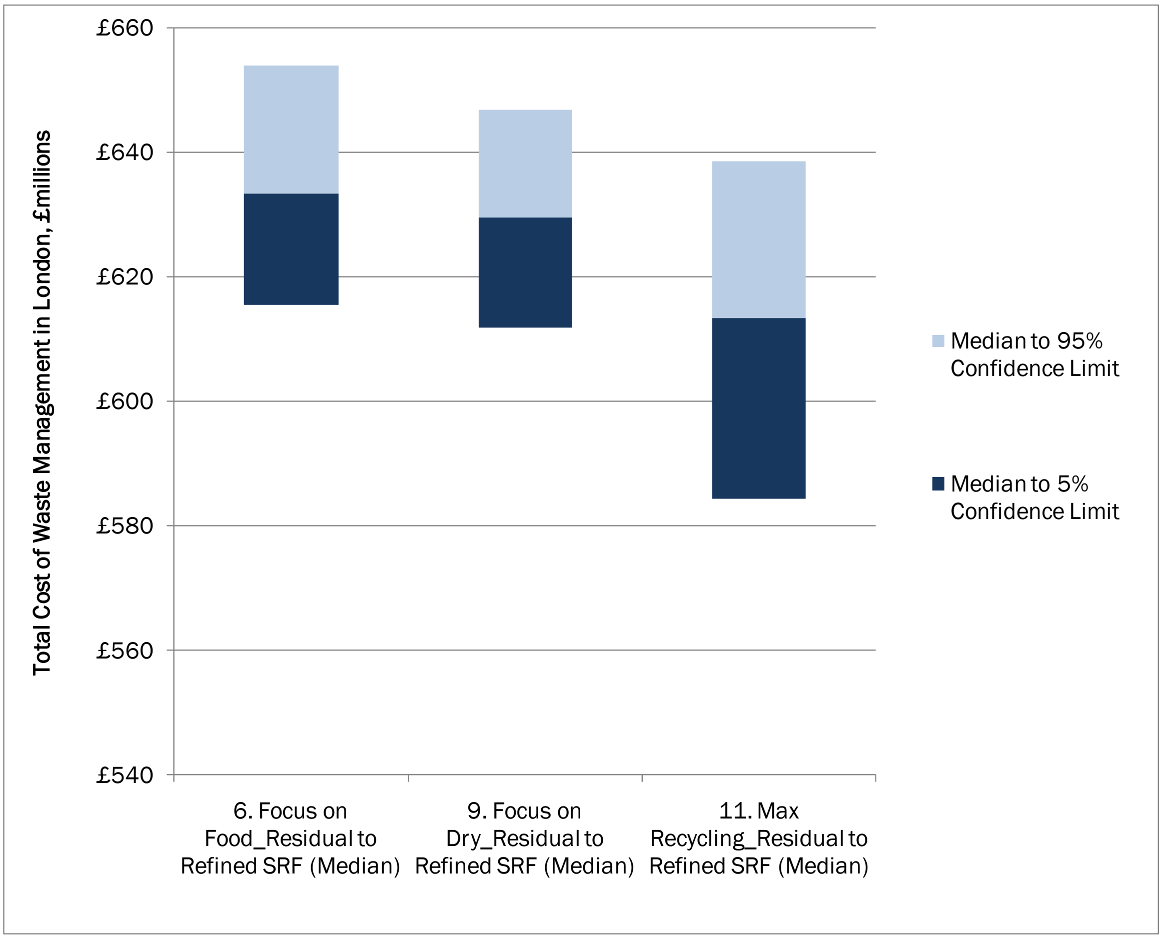


Note: shaded areas represent the 95% confidence interval around the median values.

The range of total annual costs under the different scenarios is drawn out further in Figure 9-2. This shows that the costs of the ‘focus on food’ scenario could be as low as those for the ‘focus on dry’ scenario and vice-versa. Furthermore, the costs under the ‘max GHG abatement/recycling’ scenario could extend above the median values for the other two scenarios.

What Figure 9-1 and Figure 9-2 do not show, however, is that when some of the input parameters are varied, such as achievable yields from recycling schemes, the recycling rates set out in the Draft MWMS may not be met. Such sensitivities are presented in Sections 9.2 to 9.4.

Figure 9-2: Analysis of Uncertainty of Total Waste Management Costs



9.2 Lower Performance of Scheduled Household Recycling Schemes

The aim of this exercise is to test the sensitivity of the central results to variations in assumptions relating to the performance of scheduled household recycling schemes. Scenario 6 (‘focus on dry’ with residual to High Biomass) is used as an example to demonstrate this sensitivity.

Under the central assumptions, maximum recycling levels, as reported in the aforementioned WRAP kerbside performance study, are used for each collection system in 2015, with increased captures over time such that average yields are 253kg/hhld/annum. The average upper quartile figures for London are currently around 195kg/hhld/annum, with the median ranging from 148 to 178kg/hhld/annum, according to whether a Borough is located in Inner or Outer London respectively. It is therefore acknowledged that using the WRAP data is an optimistic estimate, and more likely to represent a ‘best case’ situation in 2015. As noted in Section 8.0, pushing up the average yields from some Inner London ‘doorstep’ type dwellings by around 100 kg/hhld/annum in 5 years may be challenging, or in fact more costly than we model under the central case.

In the first sensitivity presented in Table 9-1, therefore, we have reduced the average yield achieved in 2015 from 253 to 195 kg/hhld/annum to represent a ‘worst case’ scenario. Furthermore, we have also reduced the average yield for schemes operating in 2020 from 267 to 216 kg/hhld/annum. Performance in 2031 is left unchanged, as yields are more likely to increase to central case levels within the time frame available.

In the second sensitivity presented in Table 9-1, again to present a ‘worst case’ scenario, the capture of organic wastes in 2015 has been reduced to a mid-point between central case levels and those which were achieved in London in 2008/9. Additional reductions in capture of organic wastes have also been modelled for 2020.

Table 9-1 shows that, if the performance of dry and organic waste collections reaches ‘worst case’ levels, then reaching the 45% and 50% targets within the Mayor’s Draft MWMS will be far more challenging than under the central assumptions. Under these ‘worst cases’, however, the largest margin by which the target will be missed is by 3% (under Sensitivity 2 in 2015). Although we do not believe, therefore, that this should represent a significant concern, it does suggest that perhaps a greater emphasis should be placed on the analysis of how behavioural change can be promoted in London.

Table 9-1: Sensitivities associated with Lower Scheduled Household Performance (for Scenario 6)

Case	Parameter	2008	2015	2020	2031
Central Assumptions	Total Cost	£582	£613	£596	£613
	Recycling Rate	25%	45%	50%	60%
Sensitivity 1: ‘Lower Capture of Dry’	Change in Cost	£0	£34	£29	£5
	Recycling Rate	25%	43%	47%	60%
Sensitivity 2: ‘Lower Organics Capture’	Change in Cost	£0	£37	£29	£5
	Recycling Rate	25%	42%	47%	60%

9.3 Changes in 'Non-Scheduled' Household Recycling

As discussed above, 'non-scheduled' household recycling plays an important role in meeting the targets set out in the Mayor's Draft MWMS. Again, as per the analysis in Section 9.2, we have used Scenario 6 ('focus on dry' with residual to High Biomass) as the central case by which to test the sensitivity of related central assumptions.

In the central case, the three non- scheduled approaches which increase performance to the greatest extent are reuse, RRCs and recycling from the commercial sector. As shown in Table 9-2, of these approaches, recycling from the commercial sector contributes the most towards meeting the 45% recycling target. Whilst achieving a 40% recycling rate for commercial wastes is not in itself problematic, the 5 year time frame to 2015 may not be of sufficient length to allow existing contractors to extend appropriate services.[62]

Table 9-2: Contribution of Non-Scheduled Approaches to Total Recycling Performance

'Non-Scheduled' Approaches to Household Waste Recycling	2008	2015
Reuse – contribution to total recycling in London	0%	1%
Tonnage Reused (tonnes)	*10,000*	*53,000*
RRCs - contribution to total recycling in London	5%	6%
Average RRC Recycling Rate	*46%*	*55%*
Commercial Sector - contribution to total recycling in London	1%	5%
Commercial Recycling Rate	*4%*	*40%*[1]

Notes:

1. Details relating to the breakdown of this figure are provided in the Appendix 3

Allied to this sensitivity, we have also undertaken a related 'criticality analysis'. This test lowers the overall recycling rate for commercial waste (the most significant approach to 'non-scheduled' recycling) in 2015 and 2020, and records when London's overall recycling falls below the required targets in these years.

[62] In this context, it should also be noted that at the time of writing, in response to pressure from the European Commission, Defra is currently consulting on the definition of MSW, which may be brought into line with that in other Member States, to include all commercial wastes

Under this test, in 2015 the commercial recycling rate can fall to 33% before the overall 45% recycling target can no longer be met. This fall is achievable because additional kerbside recycling schemes to those already in place under the central assumptions (for Scenario 6), can be rolled out to all London households. This finding might be viewed as encouraging, as an additional 27% recycling performance (on top of the current 4%) over the next five years is more achievable than an additional 36% to reach the 40% rate.

The findings of this 'criticality analysis' also show that in 2020, commercial waste recycling must exceed 43% for London's overall target of 50% to be met. This, again, is encouraging as current levels of commercial recycling across the UK are already estimated to be around 45%, and thus meeting a 43% rate should be achievable in London.[63] However, this change in waste flows does come at a cost. Accordingly, the additional roll out of kerbside recycling services in London to achieve the Mayor's proposed targets might require an additional £18m and £9m in 2015 and 2020 respectively.

The same 'criticality analysis' can also be used to show the impact of increasing commercial waste recycling rates above the levels modelled under our central assumptions. If these rates are increased, then fewer households would require a food waste collection service, and thus the total costs of meeting targets would be significantly reduced. For example, in 2015, if a 50% commercial waste recycling rate is achieved, financial savings of around £4M could be made under Scenario 6.

9.4 All Schemes to 'Kerbside Sort' Collection Systems

Again, for this sensitivity, Scenario 6 ('focus on dry' with residual to High Biomass) is used as the example scenario. If all doorstep and 'communal' type systems are switched to 'kerbside sort' (or 'source separated') systems by 2020, then additional savings of around £10M/annum might be achieved out to 2031. This is because kerbside sort systems (net of revenue and sorting) are cheaper to run than single stream commingled collections. It should be acknowledged, however, that there may be operational limitations to implementing such collection systems in all London Boroughs.

9.5 All Schemes to Weekly Refuse Collection

Once more, for this sensitivity, Scenario 6 ('focus on dry' with residual to High Biomass) is used as the example scenario. If all refuse collection schemes are changed so that the frequency of collection is weekly there are two key changes to the central results:

1. The lower captures from kerbside recycling schemes result in <u>none</u> of the recycling targets being achieved (by around 2-3%); and

[63] Eunomia (2010) *Landfill Bans: Feasibility Research*, Final Report for WRAP

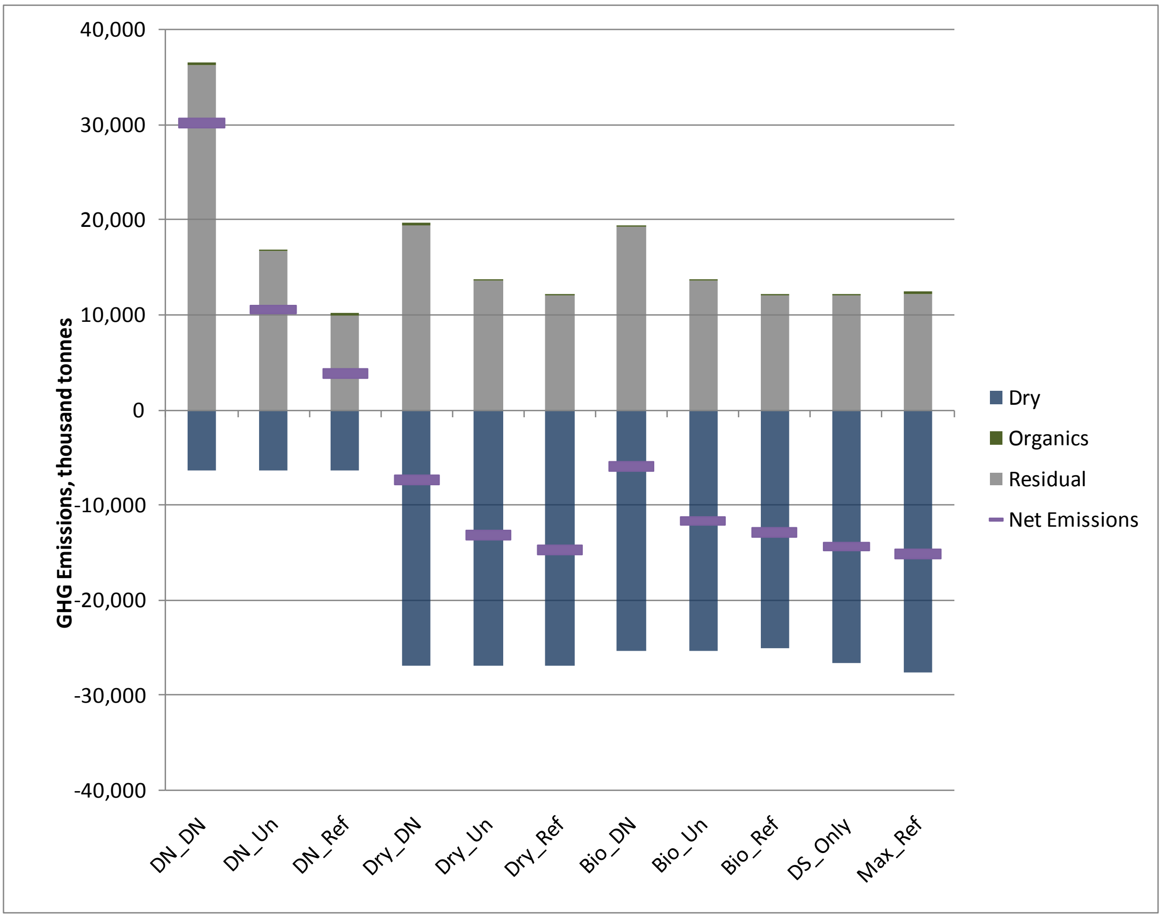
2. The total costs of waste management increase by around 5% compared to the central case.

These results suggest that it may not be sensible to propose that residual waste should be collected in London on a weekly basis.

9.6 Greater Materials Reprocessing in the UK and London

As shown in Section 8.2, waste management practices in London still generate net GHG emissions under the IPCC reporting methodology. A core feature of this methodology is that GHG benefits accrued from materials reprocessing overseas do not count. To test the sensitivity of this feature, if it is assumed that either a) all materials reprocessing occurs in the UK or b) savings from recycling overseas do count, then the net GHG emissions from waste management in London are far lower, as shown in Figure 9-3. The results show that, in all scenarios whereby the recycling targets in the Mayor's Draft MWMS are met, net GHG savings for London are achieved. These results suggest that the GLA should continue to promote new materials reprocessing infrastructure in London.

Figure 9-3 Breakdown of Cumulative GHG Emissions (2008 to 2031) assuming all Reprocessing in the UK



9.7 Additional Considerations

9.7.1 Joint Service Procurement and Delivery

In the Mayor's Draft MWMS, it is suggested that joint working across Boroughs might offer opportunities to reduce costs via economies in procurement and delivery of services. Whilst this is a variable which could be modelled with spurious accuracy by way of sensitivity analysis it is not appropriate for a study of this nature. It should be noted, however, that Eunomia's work on behalf of local authorities in the UK in this sphere suggests that joint working across Boroughs will deliver significant savings.

9.7.2 Shared Ownership of Waste Infrastructure

In the Mayor's Draft MWMS, it is suggested that shared ownership of waste infrastructure between Boroughs and the private sector might provide opportunities to reduce costs via shared risk and potentially lower rates of interests offered by Prudential Borrowing over project finance. Again, whilst this is a variable which could be modelled with spurious accuracy by way of sensitivity analysis, it is not appropriate for a study of this nature.

10.0 Conclusions and Recommendations

As stated in Section 2.0, the core objective of this study is to provide independent analysis of the financial costs and monetised GHG emissions associated with a range of waste management scenarios to 2031. To provide the appropriate context for this analysis, modelling of a 'Do Nothing New' scenario, was also undertaken.

Focusing upon this goal and based upon the results presented in Section 8.0 and the associated sensitivity analysis in Section 9.0, the following conclusions and recommendations can be made:

- Focusing waste management services on the maximisation of 'GHG benefit' could result in the lowest financial costs of any scenario modelled. The Mayor, therefore, appears to be justified in proposing recycling targets above those within Defra's Waste Strategy for England, and might also be justified in raising these targets above those published under Policy 4 of the recent Draft MWMS;
- The 'Doorstep only' scenario, whereby no further increase in kerbside recycling from communal properties occurs, and all corresponding waste is diverted to MBT processes, appears to be more cost effective than both the 'focus on food' and the 'focus on dry' scenarios. It should be noted, however, that under this scenario, not enough materials can be recovered from the waste stream to meet the Mayor's 50% or 60% recycling target in 2020 and 2031 respectively. Therefore, the GLA should not seek to propose that a significant number of Boroughs follow such an approach;
- As stated throughout this report, a lack of available, verifiable data is such that there are significant uncertainties relating to estimates for some core collection cost and in some assumptions relating to service performance, especially out to 2031. As a result, the ranges of possible outcomes for each scenario (modelled using Monte Carlo analysis) are relatively wide. Although the results of the study are of clear value, therefore, as with all macro-modelling of this nature, they should be treated with caution;
- The approach towards maximising 'GHG benefit' is also consistent with the Mayor's proposal in the draft MWMS (Policy 2) for setting a greenhouse gas (GHG) standard for MSW management activities to reduce their impact on climate change. Furthermore, Policy 5 of the draft MWMS proposes to catalyse low carbon technologies as a central element of new waste management infrastructure. The selection of new technologies modelled for each scenario, therefore, represent those which have been shown in a previous study by Eunomia on behalf of the GLA to offer better GHG performances than alternatives;[64]

[64] Eunomia (2008) GHG Performance of Residual Waste Technologies, on behalf of the GLA, January 2008

- The results of the study show that, with regard to reducing GHG emissions, all modelled scenarios perform significantly better than the 'Do Nothing' Baseline scenario. It should also be noted that there is relatively little difference in performance between the three core collection scenarios; 'focus on dry', 'focus on food' and 'max-GHG'.[65] In the recent consultation for a replacement draft London Plan, with regard to waste technologies, the GLA suggests shifting towards a more 'output-based specification to ensure the best possible environmental outcomes'.[66] It is therefore perhaps appropriate that this level of flexibility is given to the whole waste system, in that due to local infrastructure and housing stock it might be appropriate for some Boroughs to focus initial efforts on food waste collection, whilst others should focus initially on collection of additional dry materials to meet recycling targets. This might be a principle adopted by the GLA as part of the Mayor's emerging preferred method of waste management;
- The Mayor's Draft MSWM suggests that the total cost of waste management in London is in the region of £600m/annum. Albeit with the caveats relating to uncertainty outlined above, the modelling for this study indicates a similar sum for future annualised costs under any of the given scenarios. Policy 3 of the Draft MWMS suggests that this annual cost might be reduced significantly, by as much as £90m/annum in near future. Whilst these savings might be optimistic in the short-term (in light of the rising costs of Landfill Tax and the time lag prior to the construction and operation of new management infrastructure), should the benefits of both markets for recycled materials and incentives for renewable energy be realised by London Boroughs via effective procurement of new services, they may be achievable in the medium to long term;
- The targets detailed under Policy 4 of the Draft MWMS present a specific challenge with regard to the timeframe to meet a 45% recycling rate by 2015, which reflects around a 20% increase on current performance. Assuming this target is met, subsequent targets will be far less challenging, with only a further 5% required over the following 5 years to 2020, then a further 10% to 2031. In initial years, therefore, annualised collection and recycling costs increase significantly for Boroughs. Over time, however, from 2015 to 2020, total annual costs decline slightly. This is the result of combination of effects including moderately increasing costs of collection of dry recyclables and biowastes, falling costs of both refuse collection and landfill (albeit with increasing costs per tonne from the Landfill Tax escalator), such that the net impact is a year-on-year fall in total costs. From 2020, there is a need to

---

[65] Furthermore, under the 'focus on dry 'and 'focus on food' scenarios, broadly the same amount of food and dry materials require collection to meet the 2015, 2020 and 2031 targets. The main difference between these two scenarios, therefore, is in the order of roll-out of services to 2015, which is shown in more detail in Appendix 4

[66] The London Plan: Spatial Development Strategy for Greater London (Consultation Draft Replacement Plan), 2009

replace ageing residual treatment infrastructure, i.e. the Edmonton incinerator, and thus total annual costs increase once more;

- It is understood that the Mayor proposes to promote an equal level of waste collection service across Boroughs. Whilst this might be a laudable goal, it should be noted that both this study, and a simultaneous report being undertaken on behalf of the GLA focusing on best practice collection, have found that this will be extremely challenging.[67] Some residential properties are simply not designed to cope with the amount of waste which is now generated by households, and whilst innovative systems such as underground vacuum technologies are being introduced in London, these come at a significant cost. Therefore, whilst we believe, as a principle, that the GLA might seek to promote minimum levels of collection service further to those enshrined in law via the Household Waste Recycling Act, it should also recognise that the barriers are such that this might not be appropriate for all Boroughs. At the same time, however, it should be recognised that other Boroughs might far exceed these minimum services, such that the overall objective is achieved on an aggregate basis;
- The evidence base used to model the costs of different waste management methods for this study suggests that collection and recycling or treatment of source separated wastes can be less expensive, on an annualised basis, than residual waste treatment processes. The order of dispatch in our model therefore is such that new collection services are generally rolled out prior to the development of new residual treatment infrastructure. If this is the case in reality, and new services achieve the levels of success delivered by best practice examples, it should be noted that London could find itself in the situation of having an over-capacity of waste management infrastructure. Whilst such a situation is perhaps currently perceived as being very unlikely, we recommend that the GLA is mindful of such an outcome in future years. By way of mitigating this risk, Eunomia has handed over the waste management model developed via this study, for use by the GLA on an ongoing basis, to monitor and analyse future waste flows in London;
- The modelling for this study suggests that the recycling targets proposed by the GLA in the Draft MWMS cannot be met by focusing on ‘scheduled’ household collection schemes alone. Improving performance at RRCs, and in commercial waste recycling (for which municipal-led services currently perform far worse than those operated by the private sector) will be essential. Furthermore, although the contribution of ‘on-the-go’ recycling and street cleansing activities is currently minor relative to other methods, the roll-out of new such services could play an important role, not least in improving the quality of life for many Londoners, in line with Policy 6 of the Draft MWMS;

---

[67] Hyder Consulting (2010) The Performance of London's Municipal Recycling Collection Services, Final Report for GLA, March 2010

- It should be acknowledged that meeting the proposed recycling targets does depend upon significant behavioural change, especially for residents in high-density housing and thus measures must be put in place to assist this change. Whilst detailed consideration of such methods is not within the scope of this study (and costs of communications campaigns, for example, have not been included within our model), the need to inform and educate Londoners towards changing behaviour is recognised and explored in some detail under Policy 1 in the Mayor's Draft MWMS;
- The modelling undertaken for this study does not include the costs of project development and consenting, which can be significant for waste management facilities, especially in urban areas. It should be noted, however, that the revised London Plan has been designed to smooth this consenting process, particularly if applications are based upon the use of cleaner waste treatment technologies;
- Although detailed consideration of whether LATS targets will be met is not a core element of this study and has not been quantitatively demonstrated within, our high-level analysis indicates that, for London as a whole, these will be met under each of the core scenarios, as is shown within the Mayor's Draft MWMS; and
- Whilst there has been significant focus within this study (and in much previous work relating to waste management in London) on GHG emissions, it is important to highlight the potential tension between the development of low-carbon waste treatment plant and the minimisation of air quality impacts. Primarily these relate to oxides of nitrogen (NOx) and particulates (PM10), for which London is currently estimated to be exceeding targets.[68] Recent work undertaken by Eunomia and EMRC on behalf of the GLA showed that the development of new plant might result in exceedances of both NOx and PM10 in specific locations, particularly those near to busy roads. The study concluded, however, that there are large areas of London where waste treatment plant could be located with minimal effect on attainment of air quality objectives. Isolated residual treatment facilities of the types considered in this study - if managed and operating as designed - were therefore considered to be unlikely to have a significant effect on air quality where objectives are not forecast to be exceeded in the future.

[68] GLA (2002) Cleaning London's Air: The Mayor's Air Quality Strategy, September 2002

GREATER**LONDON**AUTHORITY